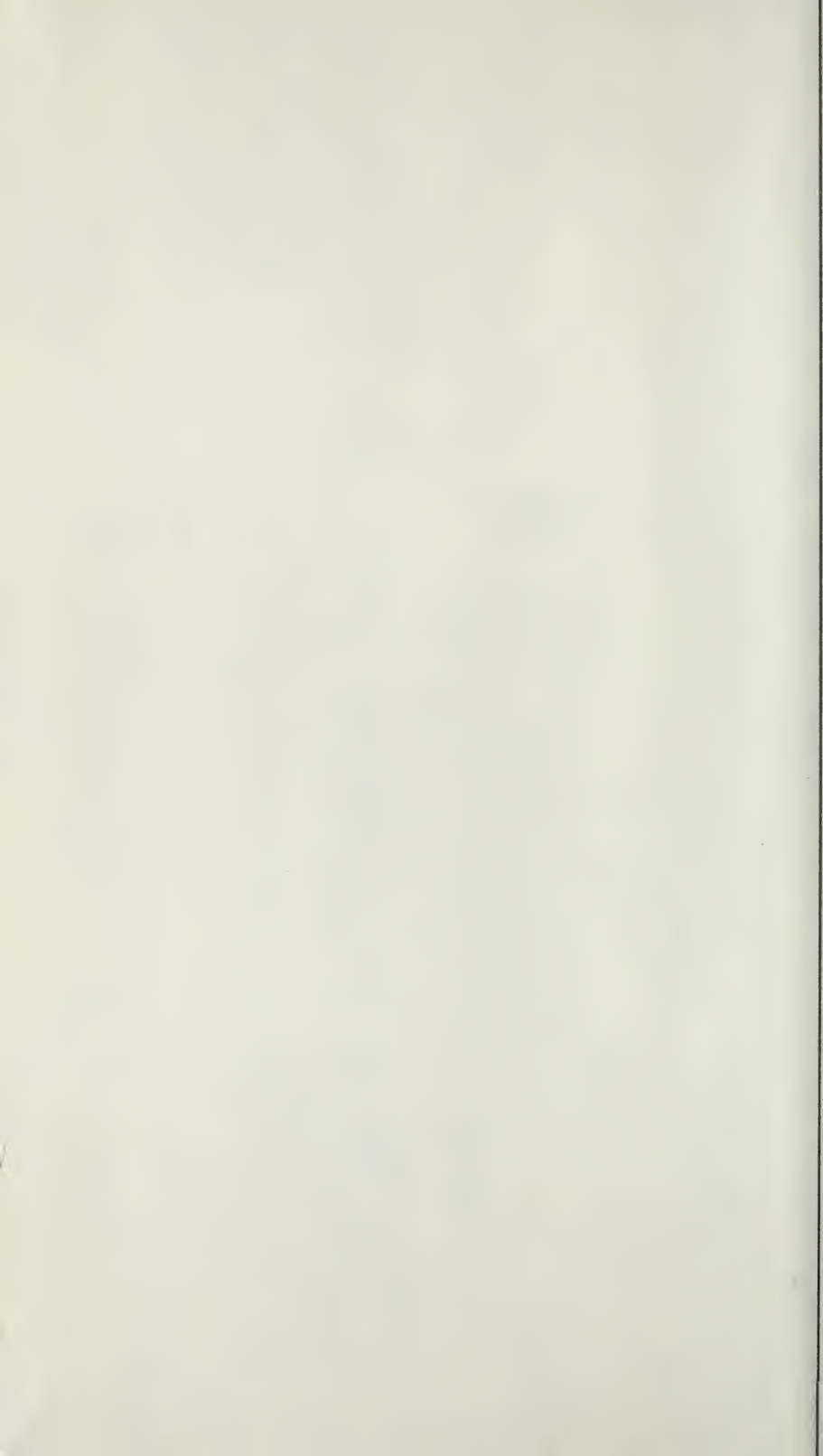


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THE CHALLENGES OF FORESTRY

*A Compilation of the Addresses and Technical Papers
Presented on the Occasion of the College's
Fiftieth Anniversary Celebration, April 12-14, 1961*



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THE CHALLENGES OF FORESTRY

*The Addresses and Technical Papers
Presented on the Occasion of the College's
Fiftieth Anniversary Celebration, April 12-14, 1961*

Compiled by

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*Associate Professor of Wood Products Engineering
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Professor of Forest Zoology

State University College of Forestry
at Syracuse University—1961

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Foreword

The State University College of Forestry at Syracuse University was founded in 1911. The intervening fifty years have been replete with significant developments both for this college and for the field of forestry. Important as these have been we can anticipate that the next fifty years will bring even greater changes.

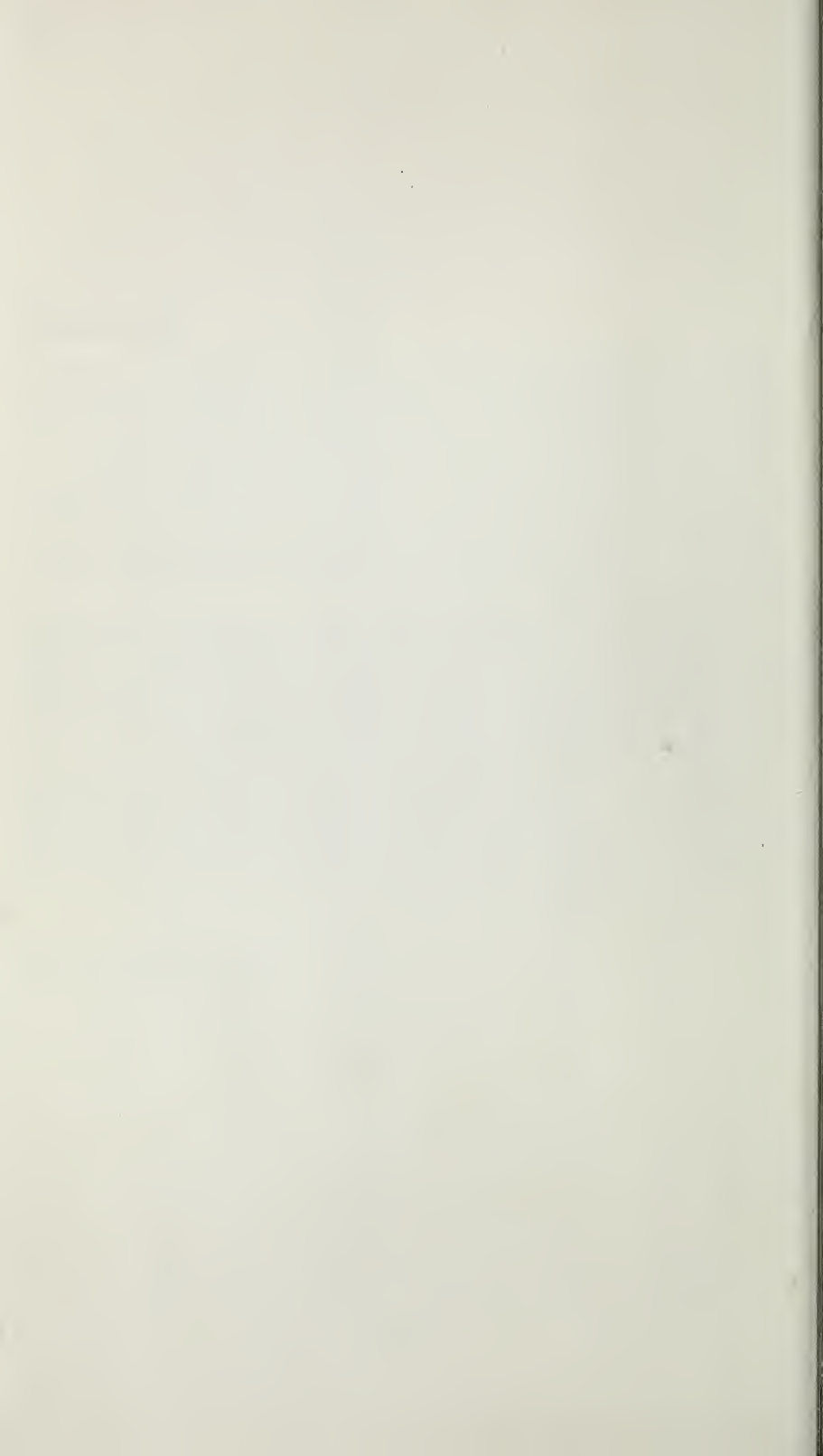
Forestry must expand in breadth to develop sound basic principles for multiple use management. It must also be alert to new special uses of forest land that an expanding population and technology will impose upon it. Not the least of these will be developing new patterns for suburbia, with forest as an integral part of the ground plan.

Forestry must grow in depth as it reaches out to incorporate in its principles and practices the new discoveries in related physical, biological, and social sciences. The scientific resources of the world are expanding at an exponential rate. To grasp the new knowledge and to bring it to bear on forest land resources and their use are the *Challenges of Forestry* in the decades ahead.

On April 13, 1961, as a part of the celebration of this college's first fifty years, a group of leaders in education, research, government, and industry presented their views on the *Challenges of Forestry*. Through publication, their views are being made available to all foresters and workers in related science as a stimulus to their thinking on progress in the future.

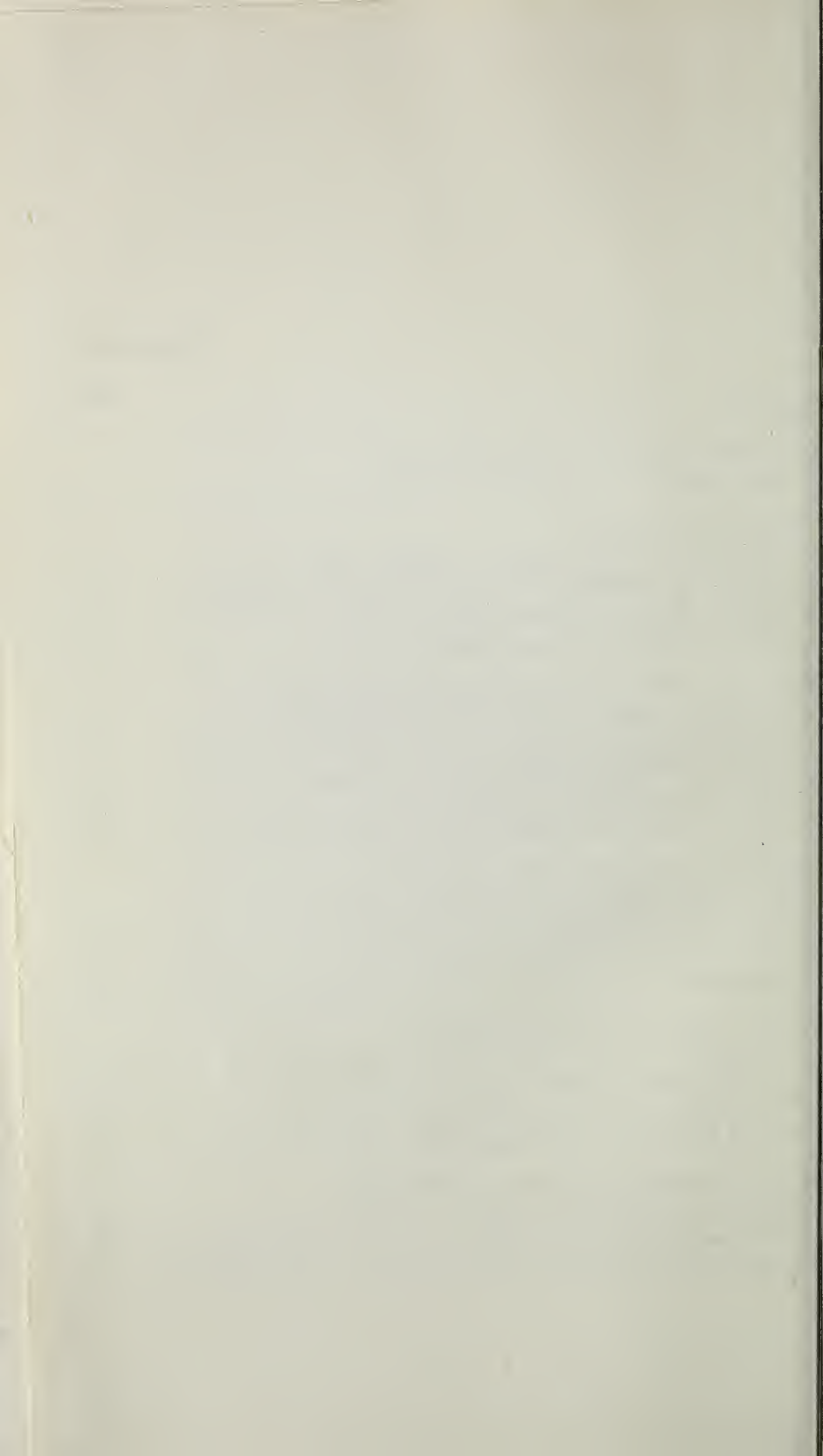
June 8, 1961

HARDY L. SHIRLEY, Dean



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PART ONE

CHALLENGES IN WORLD FORESTRY



Challenges in World Forestry

EINO A. SAARI

*Professor of Forestry Economics
University of Helsinki*

The invitation to speak to you at this memorable celebration of the Fiftieth Anniversary of the State University College of Forestry at Syracuse University is a great honor for me. This site of higher learning in forestry is not only known for being the biggest school of forestry in the western world but also is well known for its high standard of scientific and professional quality, its staff of high reputation, its buildings with modern equipment, and for talented far-sighted leadership in the person of its Dean, a world-famous forestry educator and scientist.

The Dean of the Faculty of Agriculture and Forestry at the University of Helsinki in Finland, having been invited to attend this celebration, was unfortunately not able to come. He together with all our faculty members have asked me to bring to your School, its leader, the alumni and the students their respectful greetings and their sincere wishes for an illustrious future development.

On this occasion I also want to express our gratitude to you for your kindness in having accepted here several of our graduates for further studies. All of them have been satisfied with their stay at this College of Forestry. I have been able to find after their return to Finland that the time spent here has given them valuable new ideas and improved possibilities for their further scientific or professional development. I bring to you also their sincere thanks and congratulations.

Your kind invitation to me I understand as an act of friendship toward a small country with many natural, historical and geographical handicaps, a country where forestry plays a more important role than in any other country in the world, a country that highly esteems the friendship of your great union, a small country that only with utmost efforts and sacrifices has been able to conserve its liberty and independence in this disturbed time.

When I last met your Dean Shirley he suggested that I speak on the topic, "Challenges in World Forestry." I must have been thoughtless in accepting it. Starting my preparations for this visit to America I began to think what World Forestry actually means, and I found that it was not so clear and not so simple a concept. There are several excellent books about the forest resources of the world, some of the very best of them having been published in your country, like the well known book of Zon and Sparhawk in 1923 and *A World Geography of Forest Resources* in 1956. Rather complete statistics on world forests are published periodically by the Food and Agriculture Organization of the United Nations. Good publications on world forest resources have also appeared from other countries, i.e. Sweden, Finland, Germany, Russia, etc.

In this literature we can find rich information on forestry in different countries and statistical tables including figures for different countries and their totals for regions and the world. But in most cases, this is more a collection of pictures of different countries and figures for their totals than World Forestry.

Let us suppose that we begin to study the national economy of a country. If we have a report of the economic activity of every individual and every business unit and if we calculate totals including information of all of them we still do not get a picture of the national economy, because it is something else than the totals of all individuals. There are so many interrelationships and common efforts that make the total something else or at least give it many features not noticeable in the diversified collection of individual reports.

Having come so far I asked myself, whether we already now can speak of any World Forestry in the same kind of meaning as we study the national economy of a country.

My answer was: perhaps it is still somewhat early. But there is, and there has been for a long time, a trend toward something we perhaps could call World Forestry.

Even if we say that a collection of statistics and other information on the forestry of different countries in itself is not yet any World Forestry, as complete collections as possible are essential conditions for the studies of a complicated whole we could call World Forestry in the meaning given to these words here. These kinds of compilations are at present already complete enough so that it is easy to find material for studies in World Forestry. Particularly FAO has done a great deal to produce statistics and other information. The rapid development in this field has made possible and stimulated some important studies, where the interrelationship and the interdependence of different countries and ideas of world-wide cooperation already are obvious.

Such studies are carried out partly by FAO alone, partly in collaboration with different organs of UNO and UNESCO. I may mention here *European Timber Trends and Prospects 1953*, *World Pulp and Paper Resources and Prospects 1954*, *World Demand for Paper to 1975*, published in 1960. These kinds of studies are being continued. In this connection I should like also to mention an excellent book by the Swedish professor Streyffert: *The Future Supply of Timber in the World*.

The idea of World Forestry has also begun to interest several Schools of Forestry, your College being among the first ones in this category. At the German National Institute for Forestry at Reinbek, near Hamburg, a course of study called World Forestry has for a long time had its place in the teaching and research program. I shall not try to make a complete list of other institutions with such programs. These are only a couple of examples.

We all know that this growing interest in international cooperation and better understanding of the interdependence of all countries is not confined alone to forestry. Rather, forestry is developing according to the general trend in economics

and politics. It is unnecessary for this illustrious audience to tell the story of UNO and its specialized agencies and other occurrences in the same direction.

The idea of international cooperation in forestry started at the end of the last century, first in research work. The International Union of Forest Research Organizations was already established before this century began. It still exists and is now in a state of progressive development.

During more than half a century a series of larger and smaller international forestry congresses have been organized in different parts of the world. Among the early large ones were those held in Paris in 1901 and 1913. The Italians arranged a large international forestry congress in 1926 and called it the First World Forestry Congress. The next world-wide congress held in Hungary in 1936 was called the Second. This wrong numbering of these congresses has been continued. The latest forestry congress having the name "Fifth World Forestry Congress" was, as you know, arranged with great success at Seattle last fall. The number of participants was roughly 2000, which is four or five times as many as at the earlier congresses of this series. The success of the Seattle congress proved that your organizing committee with the able leadership of your Chief Forester, Dr. McArdle, had accomplished an excellent job. The hospitality and the friendly attitude of your forest industries and the citizens of Seattle to Congress members and their families was unbounded.

Such congresses have no authority to decide anything in world forestry. But they have a mighty influence among foresters from all parts of the world in the fact that they have a common responsibility, that they can help each other, and that continued cooperation is needed.

An idea already discussed before the First World War was the necessity of a permanent world center for forestry. In the beginning some kind of a clearing house for the information coming from different countries was meant, but later in addition more significant work was planned for such an institution. The first attempt was made according to a resolution at the Rome Congress in 1926, mentioned before. A forestry bureau was established at the International Institute of Agriculture which had already been started in 1905. Initially, the agricultural people were more active than we foresters.

This first permanent world forest center remained rather modest. It did not fulfill the purpose that was expected of it. The next World Forestry Congress at Budapest in 1936 decided, therefore, that a new international forest center should be established at Berlin in addition to that one in Rome. This new one started its activities in 1939.

Unfortunately, the political situation in the world was at that time such that a large part of the world never started cooperation with this new center. In spite of the difficulties, the center accomplished a great deal of excellent work proving that it had a competent staff. Some time before the end of the war, this international forestry center was compelled to discontinue its activity, and it was never started again.

A new era in the history of world forestry began after the Second World War. The Food and Agriculture Organization of the UN was established in 1945 and, although the word "forest" cannot be seen in the name of the organization, there is a division for forestry and forest products. Soon after it was decided that the Rome and Berlin centers should be closed and FAO with the acquisition of their respective archives should carry on the work of both centers.

I have already mentioned some features of the statistical and research work of FAO in forestry. In this connection I want to mention the principles of forest policy adopted by the FAO Conference in 1951, an interesting first attempt to formulate the basic ideas of forest policy for all countries in the world. The regional offices of FAO and its regional Forestry Commissions have proved to be an efficient stimulator of the idea of regional cooperation in forestry. A very important role in the international forestry cooperation has been played by the technical aid given to countries needing this kind of help for the development of their forestry and forest industries. The UN Fund for Technical Assistance and the Special UN Fund for Economic Development have been effective means in strengthening the understanding that foresters of all countries have duties of mutual assistance where it is needed. Planning of all this activity necessitates a close follow up study of what happens in the world and what effect the development in some countries may have on the development of other countries.

The creation of such organizations as:

OEEC (Organization for European Economic Cooperation) and its successor

OECD (Organization for Economic Cooperation and Development)

EFTA (European Free Trade Association)

LAFTA (Latin America Free Trade Association)

EEC (European Economic Community)

COMECON (Economic Cooperation between the Peoples' Democracy)

has been a vigorous stimulation of the idea of regional forestry.

Particularly within OEEC and EEC have the discussions and studies of forestry and forest industries been active. In both of these organizations special forestry committees have been working. Especially interesting from the point of view of my topic have been the discussions in EEC concerning a common forestry and forest industries policy for all the member countries. EEC is a fairly intensive economic integration of six European states (Belgium, The Netherlands, Luxembourg, France, Germany, Italy) which was established in 1957. It created among other things a common market for all the member countries. In these times it is necessary to coordinate the different sectors of the economic life as much as possible. Forestry and forest industries cannot be left outside of this movement. In order to study these problems a special conference was arranged at Brussels in 1959. Forestry experts of the six member countries discussed thoroughly the need and the possibilities of coordinated activities. The discussions led to the conclusion that a more or less uniform common forestry and forest industries policy is necessary for the total EEC area, which means many adjustments in the laws and

customs. A number of recommendations have already been made, and a permanent forestry committee for the EEC was recommended. If the development will progress according to those lines we can speak of a real regional international forestry that is more than a collection of information on forestry in the six countries.

Now we may ask: why is it necessary to discuss forestry as a world problem. Is it not sufficient that it is discussed and studied in each country as a national problem?

Of course, a national study of forestry and a national forest policy is always necessary but in addition to that the international point of view is becoming more and more important. The development of world affairs seems to be such, that the countries are becoming more and more dependent on each other, particularly small countries. What other countries do will have their influence on our own country. This aspect appears to be more and more obvious in all economic life. It is the duty of our generation of foresters to take this phase of the world development seriously.

The population of the world is increasing at a tempo that is alarmingly rapid. At the same time the pursuits for a higher standard of living are getting stronger and stronger even in countries where people so far have been more or less satisfied or at least accustomed to a modest and simple form of life. And the people do not want to wait any more until conditions slowly improve. The development must be forced.

As forests are one of the great natural resources, and what is particularly important, a renewable resource, those who are experts in forestry and forest industries in the richer countries must help the poorer countries to utilize their forests in a more efficient way and in a way that at the same time will guarantee a sustained yield or, better still, a progressive increase in yield.

We foresters are happy that forestry still has vast possibilities not yet utilized. The more knowledge that we have of the forests of the world the clearer it has become to us that much greater achievements may be expected from the forests for the benefit of the population in many parts of the world.

The task given to us, foresters, is a gigantic task and a difficult one. But we must take the responsibility for its development. And we who are working as educators in the Schools of Forestry, must take our responsibility in training young men and women to become capable to solve the problems.

The latest world forest inventory of FAO shows that forests occupy an area almost 40 per cent larger than the agricultural land. Of all the forest land, 4.4 billion hectares, 38 per cent is still inaccessible. If the inaccessibility were only a technical question, it would be fairly easy to solve with modern technique. But it is also an economic problem; the timber must be extracted at reasonable cost. That makes it more complicated. But we are studying teaching and learning in order to be able to solve difficult problems. Each year the inaccessible area is diminishing, as forestry is being practiced in virgin areas.

Of the accessible forest land, so far only slightly more than half is in use. Particularly in South America and Africa large accessible areas are still waiting for loggers to come. This again means vast unused possibilities.

Of forests in use only 40 per cent is managed with working plans, even in Europe with its old forestry practice not more than 50 per cent is managed.

If we study the cutting practices, statistics indicate, that only 40 per cent can be considered good, 35 per cent fair, and 25 per cent poor. Europe, North America and the Pacific area are much above the average: 60-65 per cent of cuttings have been classified good. In Central and South America and in Africa with their vast forests only 10-15 per cent is classified as good.

An intensive research work in Europe and North America has proved that even in conditions where good or fair forestry practices have already been in use a long time, the yield of the forests can be greatly increased, i.e. in Finland the total annual growth of our forests is 46 million m^3 without bark. It has been discussed and studied what it could be with our common species without fertilization with better silviculture. The best and most realistic calculations indicate that this figure could be raised to 67 million m^3 with the drainage of the best part of our large peat lands. Unfortunately it will be a long and difficult process, let us say at least fifty years, but the possibilities are there.

Particularly in the tropical countries there is no use for a large part of the numerous species. With better silviculture these weed trees can be replaced by more valuable species, and in this way the useful output can be increased.

So far only in some exceptional cases has fertilization been regularly used. The tree breeders are developing better trees, etc. We seem to be far from realizing the full forest potential.

A Swedish scientist, Paterson, recently made a calculation, published in 1958, of the possible annual growth of the world forests. He came up to 18.9 billion m^3 . The actual corresponding figure in FAO statistics is 2.3 billion m^3 . Mr. Paterson's figure is amazing. I would not have mentioned it at all if his university had not taken it so seriously that the study was published as a Doctor's thesis.

In my opinion the method in this investigation is wrong. The author has forgotten such factors as the difference between the yield of small sample plots and large areas and the human factor concerning the forest owners and loggers. Where there is a great number of them the average will never be the maximum possibility allowed by biological factors and the progress will be slow.

In most cases it is not difficult to increase the feelings for a short period. But we foresters are responsible that timber is coming out of the forests in a steady flow and in the species needed. This gives us one of our most peculiar problems, that we generally call sustained yield or progressive yield. When we are able to arrange our forestry according to this last mentioned principle it is a proof that we are masters of our profession.

Unfortunately vast forest areas in the world are still in the stage of more extraction and destruction. It will be hard and long work to extend good forestry

practices over all the continents. But we must be able to achieve at least a trend in this direction. We have failed badly if we have only helped people to get some more income from the forest for a few years and then have left them without guidance for the development of the potential of the forests in their struggle for a materially better living.

If we foresters are wise, if we have patience, if we have sufficient knowledge not only of the trees but also of the men who work in the forests and own the forests, if we are clever enough to adjust our forestry projects to the total development of the country, we shall be able to help the human race at least for a very long time to be provided with more and better forest products for their needs in housing, fuel, packaging, paper for a high cultural standard, textiles, etc., and employment.

Whether our colleagues in agriculture and fisheries will be able to feed the approximately fifty million more people each year, is another problem. Both optimistic and pessimistic opinions can be found.

In forestry pessimistic opinions are rare. Perhaps there is sometimes somewhat too much of optimism, particularly with biologically orientated foresters who sometimes have forgotten the human and technical factors and the time element. Before all the biological possibilities are fully utilized, much time is needed and in many cases law, customs and general opinions must be changed.

Concerning these last mentioned points of view, my experience has led to the following opinion. If we want to educate students, particularly for world forestry, the human factor must have a sufficient weight in the study program. In screening people to be sent outside of their own country in order to work in world forestry problems, care must be taken, that only such persons are sent who are able to understand people living in different conditions other than in their own country, and who are able to appreciate the national peculiar features in the cultural environment they will meet in foreign countries.

Working once in the tropics as an expert sent by FAO to a government for its forest policy I often discussed with a friend of mine, who was working in a similar duty in another field, the following problem. There we were helping the people to arrange their life in such a way that it would be possible for them to buy some more material comfort. But will it help them to be happier? We were not able to answer that question. If I am sincere I must say that I had some doubt. But then I comforted myself by saying that perhaps we can help them to make their life a little easier, and even that is worth an effort.



PART TWO
EDUCATION



Challenges in Forestry Education

HENRY J. VAUX
Dean, School of Forestry
University of California

In a prophetic passage published more than forty years ago historian H. G. Wells wrote: "Human history becomes more and more a race between education and catastrophe." If someone had thought in 1911 to ask the Founders of the New York State College of Forestry to predict the outcome of such a race, I feel sure they would have expressed little doubt that education would show its heels to the forces of destruction. Had they not been strong in such a faith, they could scarcely have established this center of forestry education at a time when the forces of forest destruction still seemed to dominate the scene.

During the half-century of life of this institution, forestry education has indeed outrun the spectre of forest catastrophe. New York State College of Forestry's contributions to that accomplishment have been major ones and they merit the honor and recognition that is being bestowed on them on this Fiftieth Anniversary occasion.

But as we celebrate the College's accomplishments we are also aware that in the broader race between education and catastrophe, education has been losing ground. The current state of that race has recently been clearly put by the Rockefeller Panel in *Prospect for America*. Its authors write: "Never before has mankind lived with the fear that it might totally destroy itself; but on the other hand, never before have so many men and women had a chance to live in hope, and never before has there been the chance to release so much human intelligence, talent and vitality." To seize this chance to release these human abilities is, it seems to me, the central challenge of all education today. If education can release those abilities, we may hope for solution of the critical problems which now mark our public affairs. But if it fails to release them, the race with catastrophe must surely be lost.

Fortunately, the urgency of our educational problem is widely recognized. During the past five years our entire educational program from the primary grades through the post-graduate university level has been under close scrutiny, analysis, and revision. Forestry education has been participating actively in this critical process. The forestry faculties here at Syracuse and at many other colleges and schools have devoted much attention to problems of educational goals, curriculum, content of teaching programs, faculty qualifications, student aptitude and selection, and the myriad of other important considerations which combine to determine the success or failure of our educational effort.

In 1956, thanks in large measure to the vision and energy of Dean Hardy Shirley, the Society of American Foresters undertook a study of education in

forestry and related fields of natural resource conservation. The study was made possible by a grant from the Old Dominion Foundation. It was started under the direction of former Associate Dean Wilm of this campus and is now being conducted by Dean Emeritus S. T. Dana whose report is currently nearing completion. Bringing together as it will both the facts of the last thirty years of growth and the viewpoints of teachers, administrators, professional foresters, and employers, Dean Dana's study could scarcely be more timely. It will provide us with solid footings of fact and imaginative but seasoned appraisals of the situation on which forestry education will build for many years to come.

With such widespread self-evaluation of forestry education already under way, it would be highly presumptuous for me to attempt a definitive statement of the challenges to forestry education. Instead, with your permission, I will use my time to speak of a small number of quite familiar matters which seem to me of special importance for our understanding of the challenges which forestry education faces in 1961. My emphasis will be on education for the professional level.

EDUCATION FOR WHAT?

The first challenge to professional forestry education today is surely that of defining clearly our goal. "An education" said William James "consists in organizing in the human being powers of conduct which will fit him to his social and physical world. One who is educated is able to extricate himself from circumstances in which he never was placed before." Thus, to define our educational goal, we need some concept of the future social and physical world in which foresters will practice. This future extends from perhaps 1971, when our present crop of undergraduates will be starting the truly professional part of their careers, to the year 2000 and beyond—years with which the present forestry generation is already directly concerned.

The image of what the professional forester is changes and develops as time goes on. A few decades ago its most common identification was in terms of the jobs that forestry practice requires in the woods or in the mill—the image of the forest fire fighter, the tree planter, the timber harvester, or the dry kiln operator. Although that image may still be too prevalent in the minds of laymen, the self-image of the profession is a more sophisticated one today. It shows the forester as a man whose function it is to decide questions of what to produce from the forest and what forest and wood technologies best meet production needs. He decides these questions on the basis of a thorough knowledge both of the science of forests and of wood and of the significance of these resources for the human activities which they serve.

Is this an adequate image to guide our educational programs in the future? Both the experience of the past half century and the trend of contemporary society suggest, I think, that although these conceptions will remain fundamental to professional competence, something more must be added to the generally understood image of the profession.

In a very real and direct sense, what can be accomplished in forestry depends mainly on the degree of public awareness and understanding of the role of forests and of wood in relation to mankind. Foresters may design management and utilization programs of high technical competence. But if such programs are to be successfully applied, the forester must not only make his operations serve the needs of people but he must also interpret them so that their meaning is clearly understood by the broader, non-professional community which ultimately determines and limits our action.

Thus, a further major feature of the professional forestry image must be that of the forester as the integrator of the forest with the whole culture of which the forest is a part. Unless the forestry profession can fulfill this integrating task, we will find ourselves limited and frustrated in trying to achieve forestry goals which we recognize as essential. We will fall short of the central professional obligation of making our forest and wood resources of most benefit to society.

From an initial orientation which was much concerned with techniques and the jobs of forestry, our education has been making good progress, it seems to me, toward the goal of the forester as a scientist-manager. Both the scientific foundations and the equipment for decision-making are continually being strengthened in almost every professional forestry teaching program. But we have as yet hardly begun to analyze, much less deal with, the problem of the educational needs of the forester who will perform the strategic function of integrating, interpreting, and linking forestry to the rest of society in a fashion most meaningful for that society.

THE CHALLENGE OF SCIENCE

Against these suggestions as to the nature of our educational goal, let me take up a few matters which define more clearly our challenge. The first of these is the revolutionary progress of science. The theme is too familiar to require elaboration here. The challenge it presents is best illustrated by two minor statistics. First, the decade 1950-1960 saw publication of more scientific information than was published in all previous history; and second, 90 per cent of all the scientists the World has produced are alive today. The implications of these two facts for the future seem to me literally staggering. The labors of Hercules—the Paul Bunyan of the Ancient World—in cleansing the stables of Augeas were trivial in comparison with the task of keeping track of the advances of science which are relevant for forestry, much less making the needed adaptations and applications of these advances. Yet forestry education must enable the profession both to keep abreast of the scientific revolution and to be an active participant in it.

The challenge of science is sharply intensified by other factors. Until about 1945 or 1950, there was a relative surplus of forest land in the United States. At least in the West, we still had a forest frontier. And as long as that frontier remained, both forest management and the utilization of forest products were limited to a relatively low order of intensity. Now the forest frontier has closed.

Although we are only beginning to feel the impact of this significant event, its consequences will surely parallel closely the developments in farming which followed the closing of the agricultural frontier some sixty years ago. Just as that event stimulated massive applications of science to farm technology, principally through improvement of soil fertility, improvement of genetic stock, suppression of insects and diseases, and widespread application of labor saving devices, similar developments in forest management have inevitably been triggered by the closing of the forest frontier.

The economic pressures which have stimulated scientific development of the utility and convenience of food products for the consumer suggest analogous trends for wood products.

So we must not only keep up with the electrifying growth of scientific information but must also understand and apply it to forestry problems on a significantly broader scale than ever before. This problem was well stated the other day by the Dean of one of our University's engineering colleges. He said: "Consolidation of our new knowledge into broad laws is the great challenge confronting practicing and teaching engineers. With mountains of new facts arising almost monthly, there is urgent need for a Euclid, a Newton, or an Einstein in engineering who can draw broad formulations and generalizations from seemingly unrelated data." Our need is surely as urgent for a Darwin or a Wallace in forestry.

THE CHALLENGE OF HUMANITY

Forestry shares with engineering, the medical professions, and others similarly based on science a position midway between Science and Humanity. The challenge of science which the forester sees when he looks at his woods is matched in complexity when he turns toward the society which he must make his forest serve. Again, the closing of the forest frontier has sharply intensified the problems of adapting forest production to the needs of the people. So long as the frontier was there the multiple value potentials of the forest could be realized in satisfactory amounts without engendering more than local and limited conflict. With the closing of the frontier, we find that the concept of multiple use defines a major problem as well as providing the framework for its solution.

Perhaps we have not yet evolved some of the techniques and some of the information needed for identifying the best combination of uses for forest areas having multiple value potentials. But a far more grievous failure is reflected in the fact that much of the public at large gives little acceptance to foresters as having professionally qualified judgment on the issues involved. Despite valiant efforts by some in our profession, important segments of the public are either ignorant of the forester's qualifications for evaluating multiple use problems or look with actual mistrust on his advice. We have not thus far established for forestry as a profession the public acceptance which is essential to the achievement of our professional goals. To provide the basis for gaining such acceptance must surely rank high among the challenges to professional education.

The present conflict among competing forest uses in which the forester finds himself occupying properly but uncomfortably the difficult middle ground is only one example of the increasing importance of the humanitarian or social side of the professional function.

As little as two decades ago the concern of most people with the forest was remote, so long as their needs for wood products were reasonably effectively met. But a combination of increasing population, increasing income and leisure time, and an amazing increase in individual mobility is rapidly changing this outlook. An important fraction of the public now thinks of forests in terms of immediate and personal experience. Thus, the forest as an environment, as distinct from the forest as a source of products, is more significant today than ever before both in the calculus of forest values and in the personal experience which determines the public view of forestry. The trend is almost certain to extend this emphasis on the forest as an environment affecting an increasing proportion of society's activities. Almost any forest manager in the West today will tell you that his most important problems are "people problems" and I suspect that his eastern and southern colleagues would echo the same theme. In so doing they are testifying to this growing importance of the forest as environment.

The implications of this trend for professional education are clear. Qualifications based largely on the science and technology of forestry have up to now been considered adequate for professional purposes. But such qualifications provide little basis for dealing with the problems of people. And the very foundations for understanding such problems rest in those areas of social science and philosophy which have been regarded as of least importance to professional competence in the past. Thus there is need for much more emphasis on these areas as a matter of professional qualification. This emphasis cannot be bought merely by subordinating some presently established aspect of the curriculum. For example, the rising value of the forest as environment might suggest a corresponding diminution in the importance of wood utilization for forestry. But from the standpoint of the forestry profession I have defined, just the opposite is true. Indeed, because of the rise of other uses, clear understanding of the role of wood utilization is more important for good forestry today than ever before. The reason for this apparent paradox is that a great many people who are now keenly aware of the social values of the forest environment think of wood utilization as reflecting a narrow special interest. They are oblivious to the fact that wood provides almost one fifth of all the physical structure raw materials used in the United States. They are ignorant of, or perhaps deliberately ignore, the broad economic and social values which result from this simple fact.

In view of the strong influence which the general public exerts on forest policy, such public myopia as to the full range of forest values represents a serious threat to truly wise forestry. It can only be corrected by a profession which retains full command over its technical and economic foundations, at the same time that it is strengthening its ability to influence effectively the public view.

How to educate foresters to deal with this humanitarian side—the people problems—without transcending all reasonable bounds of subject matters is a challenge ranking with that of adequate attention to the results of burgeoning science.

WHAT KINDS OF PROGRAMS?

If the evaluation which I have just attempted is anywhere close to the mark, then the Challenge of Science and the Challenge of Humanity pose some specific problems with which forestry education must deal both effectively and soon.

First, it must provide men who are capable of advancing forest and wood science at levels of specialization deeper, and therefore of necessity narrower, than those which are characteristic today. Yet it must also provide the scientific synthesizer who is competent to draw together threads from a diversity of disciplines and bring them to bear on practical problems in the use of a resource so complex that it cannot be understood in terms of any single scientific discipline.

Second, forestry education must provide men skilled in managing the land with understanding of the biological community with which they work and with the technical know-how required to make their work both effective and efficient. Yet it must also provide men who are skilled in managing the people who manage the land, whether these be the employees who execute technical programs or the users of the land whose impact on forestry is steadily increasing.

And finally, forestry education must provide men who understand the culture in which they live sufficiently clearly to organize forest production and use effectively in the social interest. And it must provide men equipped to interpret both the forest and the forester's management of it to the non-professionals who make the decisions which are ultimate for forestry, whether these decision-makers be the Members of the Board, the Members of the Congress, or the members of society at large.

A man who carries out any one of these essential roles effectively may claim full professional stature. A few may perform successfully in more than one of them. But it is perfectly apparent that no individual can be educated to fulfill all of these vital professional functions. Thus forestry education must be designed to achieve a number of different goals, some of which may require widely variant aptitudes and subject matters.

In meeting this need we are fortunate that forestry education in America has evolved from somewhat diverse origins and under a number of contrasting philosophies. The resulting diversity of educational approaches is surely a prime requisite if the system is to be successful over the range of goals that I have outlined. To maintain such diversity and to add new approaches where the existing ones are inadequate for the goals to be achieved should be a cornerstone of our broad educational policy. It is a cornerstone which will require vigorous defense because it is in some respects in conflict with the important concept of educational standards.

Along with maintenance of a diversified structure in forestry education itself, more effective means are needed to attract to forestry talent produced elsewhere in the educational system. Under existing patterns of graduate education in forestry, there is a tendency to insist that the man going on for advanced specialization in forest science should first have completed the equivalent of a forestry degree. Although this policy has certain justifications, it appears to have two major shortcomings. First, it seems unlikely that forestry education alone will produce enough men, qualified and interested in continuing to the Ph.D. level, to meet the prospective demand for highly trained researchers. Second, the very breadth needed in professional education means loss of efficiency in educating a specialist.

Both these problems can be avoided by developing within the graduate forestry schools programs for men who, as undergraduates, majored in chemistry, physics, botany or some other science basic to advanced forestry research. These programs would be designed to develop the interest and ability of such men in applying their basic training to problems in forest and wood science, and at the same time to provide them with whatever orientation to the professional field seems essential.

WHAT KIND OF FACULTY?

The most critical factor for the success of any educational program is, of course, the quality and character of the faculty. The goals that I have described suggest some of the faculty qualifications essential for achieving them. Of course it goes without saying that teaching interest and skills are the first qualification. The faculty as a whole should reflect a degree of balance with respect to the range of educational goals. It should include some research scientists, some people with a strong orientation toward management in the broadest sense of that term, and some whose interest and skill lies in the area of interpretation. Particularly in relation to the latter two categories, intellectual maturity and a background of some personal experience with the function in question would be virtually mandatory.

Qualifications outlined in these terms do not seem to bear too much resemblance to our existing criteria for faculty recruitment. In looking for staff, the current practice of most institutions (my own included) is to look first for people with the Ph.D. As a symbol of research competence, the Doctor of Philosophy degree would be an appropriate qualification for the scientific specialist and synthesist in forestry education. But it would seem to have little value and might even be harmful in the background of a teacher with responsibilities for either management or interpretation.

The second qualification which most department chairmen usually mention when scouting for new faculty is a background in a specified subject matter, or better yet, several specified subject matters. In other words, the faculty is recruited to fit the curriculum. This practice, too, would tend to prevent selection

of the strongest possible faculty. If strength is measured in terms of understanding of the goals I have mentioned and of ability to teach the functions thus identified, the matter of the particular subject matters used as the instrument for such teaching is of secondary importance.

Current practice makes the faculty subordinate to the curriculum. Shouldn't we turn it just the other way around? Recruit a faculty with the ability to develop men of the kinds that we need, and let the forestry portion of the curriculum reflect their individual choice as to the most appropriate subject matter for their purpose. If this suggestion seems revolutionary, let me remind you of James B. Conant's remark: "Education is what is left after what is learned has been forgotten."

To attempt to build faculties along the lines I have just suggested will be challenging indeed for any Dean. He will have to find ways around some of the most firmly established institutional preconceptions about faculty qualifications. And if he treats matters of curriculum as cavalierly as I have just done, he may find himself at serious odds with the Civil Service Commission, the Committee for the Advancement of Forestry Education and others concerned in one way or another with professional standards.

Moreover, insofar as he needs men of maturity and experience he must contend with two other serious difficulties. One is the prevalent policy of recruiting faculty members at the Instructor or Assistant Professor level. One cannot expect to buy experience in that market and the overall strength of a faculty may be weakened by inability to bring in men of established professional background. Even if existing institutional policies were modified in this respect, the developing patterns of terms of employment in both government and industry present increasingly serious obstacles to securing faculty members with substantial experience in professional practice. A man with ten or twelve years of accumulated retirement benefits in a particular system is usually past the point where even a generous faculty salary scale is financially attractive.

The problems of staffing are all the more difficult because their causes usually lie entirely outside the control of the forestry school. Yet some kind of solution for them must be found if we are to meet the challenge of providing on our faculties the strongest and best balanced teaching talents which the profession can muster.

WHAT KIND OF STUDENTS?

Finally, there is the challenge of the student. A forestry profession with the broad range of functions that I have described is going to need students of the highest quality and of a diversity of aptitudes. To date, the profession has been most successful in attracting men with a technical and scientific bent, characteristics which we shall continue to need in increasing numbers. But perhaps the "mix" of students should be enriched with more of those with primary interests and aptitudes for the human side of forestry problems.

I suspect that the appeal of forestry to high school students selecting a career still rests heavily on concepts that are either obsolete or naive. Certainly many students are attracted to our field by the notion of an outdoor occupation, of close association with nature, and of freedom from some of the trammels of a highly organized society. I would not argue against the validity of any of these concepts as a partial, though wholly inadequate, characterization of forestry. But I would ask the question: Do they not serve as a hidden but powerful device for student selection, in effect deterring the entry into forestry of the men who are primarily motivated by problems of human beings? Should this be true and if orientation toward humanity is as strategic for forestry progress as I have maintained, the task of creating a more accurate image of the forester in the minds of potential students is a major one in terms of both importance and difficulty.

Finally I come to perhaps the most important challenge of all. The combination of appropriate educational programs, highly qualified faculties, and able students selected in the light of needed aptitudes may still fall short of successful educational achievement if the people involved lack a driving motivation. When this College of Forestry was established in 1911, a notable characteristic of forestry was the crusading spirit of the foresters. Such a spirit seems to have been one of the essentials for the forestry accomplishments of the first part of this century. And the crusading atmosphere was admirable as a means for arousing the interest, enthusiasm, and devotion needed for effective motivation of men toward forestry.

Fifty years of growth have resulted in a forestry policy in America which rests on broad economic, social, and cultural grounds. The approach to forestry problems today is based much more on the facts of the scientist, and the reasoned judgment of the practical philosopher than on the zeal of the crusader. Surely, this is a sign of maturity which we can welcome and commend without derogation of the founders of the profession. But as the crusading element in forestry has dwindled, we have lost a principal source of the energy which drove forestry ahead in its early years. Today, with all the increased sophistication of our approach to forestry, the public image of the forester lacks some of the dynamism that it had a half century ago.

I do not mean to imply that the forestry profession today is less far-sighted, less devoted, or less committed to ideals than was true in 1911. Vision, devotion, and commitment characterize the forester of 1961 as much as his predecessor of fifty years ago. But skepticism is inherent in forest science and pragmatism is essential for the growth of forestry practice, and these attitudes allow little room for the emotion of a crusade. As a result of attenuation of forestry's emotional appeal, we have lost a magnet which was important in attracting young men of earlier decades toward the profession and in motivating them toward maximum academic and professional accomplishment.

This situation has developed at a time when dramatic new fields have been emerging to spark the imagination of the student generation. But equally powerful bases for motivation are now available to us which were not at hand in the

days of crusade. What we need is to make clear to non-professionals in general and to students in particular the essential fact that Dr. McArdle and Dr. Morgan have depicted so well this morning. That is that the problems in the use of wood and of forest land involve the same order and depth of intellectual challenge as those inherent in the conquest of space, the harnessing of atomic energy, or the explanation of photosynthesis.

Similarly, solutions of the problems in the use of wood and forest land involve consequences which, in the long run, may have results for society and humanity commensurate with solutions to problems of international tensions, of the psychological erosions of industrial society, or of health and disease. We in forestry have recognized and understood these facts. But we must make them much clearer to non-foresters if forestry education is to continue to attract in its students the intellectual talents that we need and to inspire in them the maximum of motivation.

CONCLUSION

Although to deal successfully with the several educational problems that I have tried to describe this morning will not be easy, I am confident that forestry education will meet these challenges. But to achieve only this will not have been enough.

Long ago Gifford Pinchot pointed out that the concept of forest conservation was much more than wise use of forest resources. He recognized it as a major instrument for accomplishing a broad range of social ends. For example, he often cited the potential usefulness of foreign forestry assistance as a tool in the solution of problems of international understanding. Our own recent experience with foreign technical assistance makes it clear that such opportunities are indeed significant and that they can only be realized through careful educational preparation. It has been said that nothing either wise or decent is given to the world without a sense of the future. Forestry is uniquely adapted to help the world to regain that sense of the future.

To recognize and to capitalize on potentialities such as this for helping to solve the major non-forestry problems of our times is a lofty challenge which I think we still must face. I hope we in forestry education will recognize and accept that challenge. By doing so we can renew the sense of urgency in forestry education which enabled it to win the race with forest destruction, and we can help to deal with today's challenge to humanity—the race between education and catastrophe.

Some Notes on Professional Education

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It is with real pleasure that I join in the celebration of the fiftieth anniversary of the founding of the College of Forestry. In this comparatively brief span of time (I have now reached the point where I feel obliged to look upon 50 years as something less than middle-age), this institution has attained a reputation both excellent and international, and it is proper that we commemorate on this anniversary this achievement of excellence, this attainment of world renown.

In a rather general way, I have been aware of the quality of the College of Forestry for a long time; but this was made abundantly clear to me just a few years ago when, given some responsibility for recruiting faculty at another university with a school of forestry, I discovered that the professionals of *that* school invariably insisted that we steal faculty from *this* one. If imitation is always a high form of flattery, I would suggest that, among universities, the consistent and undisguised threat of piracy is evidence of even greater esteem.

On the other hand, the international nature of your responsibilities was re-emphasized to me shortly before I joined State University of New York when I met several of your faculty members in the research facilities of the University of the Philippines in Los Baños. And, in our time, this is becoming a commonplace thing. In effect, the truly boundary-less scope of higher learning, taken for granted in the fifteenth century, then woefully misplaced, has only recently been reaffirmed—and you have cause to be proud of the significant contributions you have made to this important reaffirmation. Let me, then, join in congratulating the faculty, the staff, and the trustees of this institution on the job which has been done. Your reputation is good and it is wide.

My remarks tonight will be directed to a few of the problems now facing professional education in the United States. Certainly this is a field in which I pretend to no expertise, but this fact has never stopped me from talking before, and it will not, to your great misfortune, stop me tonight. As a matter of fact, my position calls for me to address myself to so many topics for which my background is inadequate, that I usually think of myself as a sophistic circuit rider.

And yet it could be maintained that the fact that the College of Forestry has achieved the eminence it clearly has, implies that you have already solved a good many of the problems of professional education. And if this were a static society, a society satisfied with what it has learned and unwilling to alter its view of itself or of its constituent parts, then it could be said that your work would be finished. But this, happily, is not the case. As a people we have come to know enough to know what we have yet to learn. While we may yearn for an earlier stability, our society as a whole has committed itself to the necessity of change. And, so

long as perfection is denied us, our social institutions will—and must—continue to evolve, hopefully but not assuredly, for the better.

The university, and of course professional education, find themselves most squarely in the flux of our time. Both (to think of them separately for a moment) have considerably altered their basic premises over the past fifty years, and each has reflected its views upon the other. But professional education, it seems to me, has contributed more to the changing nature of the university than the university has, in turn, worked upon it. I am thinking of the fact that 100 years ago there were, for all intents and purposes, but four professions represented in our institutions of higher learning: the medical, legal, theological, and teaching professions. But today, as Earl McGrath has recently reminded us, there are over 2200 professions requiring highly trained practitioners, with from 10 to 20 new ones added annually.¹ This fact has put a terrific strain upon the university, of course, for in the last analysis it is the university, while responsive to society, which must decide to what ends it will devote its limited resources. The problem, you will recognize, is complicated by a general failure to define in any precise way what, in fact, a profession is, or ought to be—what mode of life it demands, what responsibilities it entails, and what competencies it requires. While extended concern with this question of definition is hardly warranted tonight, it still remains true that we must know what attributes we wish to encourage before beginning the more arduous task of deciding what institutional forms are most likely to induce these attributes.

This is, as Mr. McGrath's figures would indicate, a very confusing problem. And it is confusing, in no small measure, because of our great desire for status and symbols. Whether it be the man who openly bleeds to ensconce himself in a carpeted office behind a desk (not oak, but mahogany), or the man who places great value on title, it is simply true that, as a nation, we are inordinately interested in achieving status—so much so, I believe, that the net effect is extremely unhealthy. Thus, very few people these days, particularly if they have had the advantage of a college education, want to be considered as engaged in a vocation. On the contrary, they would like to be considered professional men. I shall not risk giving offense to any particular group by naming names, but I am certain that you can all quickly recall groups of individuals who speak of their calling as a "profession" when it would seem perfectly clear that to categorize the occupation in this fashion involves a real exercise of the imagination.

At this point, then, it might be useful to sketch out at least some of the attributes which an occupation should have before it is to be designated as a profession. The establishment of such criteria may appear arbitrary, but, unless we are to call all work professional, their formulation would seem to be necessary.

First of all, then, a profession should be of such a nature as to require education at the higher level to permit an individual to practice it. This means that

¹ Earl J. McGrath, *Liberal Education in the Professions*, Institute of Higher Education (Teachers College, Columbia University, 1959) p. 2.

the professional activity should be based upon and grow out of a sizable body of knowledge, at least some of which is directed toward a practical end. In most cases, and increasingly so, this education extends beyond the undergraduate degree, although one cannot be doctrinaire on this point.

Secondly, a profession demands that its practitioners be capable of and entrusted with a considerable degree of individual responsibility. In other words, the professional, by definition, exercises discretion and makes decisions, and is capable of doing both because of the qualifications imposed upon him by his colleagues. His pre-entry learning and experience must, therefore, equip him with the humane and specialized knowledge necessary to make wise decisions on his own.

And third, and perhaps most important of all, a profession at maturity is always characterized as concerned with the public interest, which is to say, that, governed by a code of ethics, it demands of its practitioners an allegiance reaching out beyond the requirements of personal benefit or judgment. It creates and sustains a value system, pertinent to its special activity, but subsuming the individual exercise of that activity, even when the result is economic loss.

These three requirements, then, I believe constitute the basic, the minimal, characteristics of any vocation seeking the name, "profession." And I think, if we look closely, that they give us some useful clues about the nature of the higher learning which should be prerequisite for one seeking to enter a profession. Not incidentally, they also indicate the *kinds* of changes which professional education has worked upon the university, and the university, in turn, upon professional education.

First of all, let us be clear that, in the main, the professions have been and continue to be primarily concerned with technical or specialized competence. This is the barrier to entry which no aspiring candidate can successfully avoid. In certain professions he might, even today, satisfy this requirement without much higher learning—in apprentice programs or with long experience—but, regardless of this, he brings to the entering level a capacity to operate technically. He has learned the rudiments of his practice. In this important sense, professional education represents "utility"; it confesses an abiding interest in the practical.

The Western university tradition, on the other hand, has historically professed a primary concern with theory, rather than practice. With its intellectual roots in ancient Greece, and subject to some vacillation over the years, it has steadfastly deprecated utility and favored disinterestedness.

This apparent antipathy has irritated and confused the purposes of higher learning for hundreds of years, for, unlike the more profound theorists, some have made the assumption that liberal studies are qualitatively superior to practical studies on the one hand, and, on the other, that some subjects are inherently liberal and other inherently pragmatic. The fact that business administration can be taught liberally or that Latin literature can be taught illiberally has been totally lost on some of our colleagues. And it is this body of opinion which has

been most vocal in proposing that the university must choose—that a commitment to the liberal involves a denial of the practical.

Now, that there should still be a lingering but tenacious allegiance to this point of view is as much the fault of the professions as anyone else. What I am getting at here is the very real propensity, only now relaxing, of the professions to demand that their practitioners pay attention only to the *first* of the attributes pertaining to professional life. Consistently, the various professions have insisted that students "cover the field" technically, that they emerge from four or five (or indeed eight) years of study, with specialized competence, sufficient not only to begin to practice but to measure up to all of the known contingencies which might conceivably arise in the field. This point of view, especially in a time of rapidly expanding knowledge, has resulted in an extremely crowded and extremely narrow curriculum. You all know this; and you know, too, that the graduate, not infrequently, has been dehumanized in the process. And the genuine humanist, confronted with this result, has, with some justification, been horrified.

But it is very encouraging to note that the professions themselves, confronted with the same spectacle, have also expressed, if not horror, at least considerable dismay. This dismay, of course, arises from a number of considerations, only some of which are shared by the humanist. And I think that, by getting at some of these considerations, we might better visualize some of the key problems professional education is now attempting to solve.

In the first instance, the simple truth that a man is a human being, before, during, and after he is a lawyer or a forester, is coming to be re-emphasized by those responsible for professional education. This is a fact which the university, *per se*, has insisted be recognized from the very beginning. And, if the professional disavows any *direct* responsibility for cultivating the intellectual virtues proper to man as a man—to man as thoughtful, decision-making citizen—he now increasingly is willing to permit other faculties of the university to assume this responsibility. Thus, intellectual experiences of a non-professional nature are finding their way back into the professional student's life.

Aside from this tendency, an equally compelling argument for nonprofessional studies is fast arising, in spite of the apparent paradox, from the very requirements of the modern, mature profession itself. This, it would seem, has two main facets. The one concerns the ethical attributes of the responsible professional man; the other has to do with the nature of the specific disciplines which he must master.

In the first instance, the professions are uniformly being made aware that at any given point in a practitioner's development it is likely that his chief failings will be those totally unrelated to specialized function. It is with the assumption of responsibility which extends well beyond his technical problems that the professional increasingly finds that he must rely upon liberal studies. A few years ago I wrote of this dependence in relation to the engineering profession, but I think what I said has general application.

"The engineer at the head of a multi-billion dollar project will find that he must have some knowledge of, and be able to communicate with, the practitioners of law, of finance and of politics. Here, as many an engineer has learned to his considerable discomfort, blueprints and formulae prove unsatisfactory as media of communication. Thus it becomes clear that the engineer of the future must be . . . at least an adequate generalist in . . . those liberal disciplines which permit him to understand something about the nature of the physical and social world and the human beings and their works with which that world is populated."

What I am suggesting here is that the engineer must know, not only *how* to build a bridge that will last, but *why* the bridge should be built in the first place, what economic and social effects it is likely to have on the surrounding community, how it can be made aesthetically pleasing and, important too, how to convince all those concerned with the project of the propriety of following one course and not another. I would suggest to you that so long as he is unable to satisfy these last responsibilities, he is something less than the professional he supposes himself to be.

I would turn now to the changing nature of the specific disciplines which the professional must master—from the concept of the professional as generalist to the professional as representative of highly developed, specialized competence. Here, if I read correctly the judgments of those who are far more knowledgeable than I am in this field, there is considerable agreement on the need for more emphasis upon principles rather than techniques, a greater concern for the basic as opposed to the applied, a need for intellectual flexibility and the capacity to *contribute* to and comprehend changed conditions, rather than the ability to deal with the machinery, the hardware that happens to be in use at any one time.

In years gone by, we have, on occasion, built into professional education an automatic obsolescence; in other words, we find that we have educated professionals who, ten years after graduation, are no longer able to cope with the developments they find characteristic of their profession. If this tendency is to be corrected, inevitably we must insist upon a far greater emphasis upon the root disciplines of a given activity—economics, mathematics, physics, zoology, botany, to name but a few—even if this entails the elimination of courses concerned only with contemporary practice.

At this point some of you might well be irritated with what I have suggested. And in a way, I shouldn't blame you, for there are difficulties here which one can too easily gloss over. In rationalizing the need for liberal studies on the one hand, and the basic disciplines which undergird the profession on the other, it is altogether possible to decimate the professional curriculum in such a way as to foster an inability *ever* to come to terms with the problems of application. The possibility of impeding the professional's practical energy, of handicapping his ability to cope with real problems in a real world, is one which cannot be overlooked. We might, indeed, throw out the baby with the bath.

It is also possible that, without careful thought, we shall attempt to satisfy our acknowledged need for a broadened liberal base by arbitrarily assigning professional students to courses of study which are only ostensibly liberal, but which, in fact, are more circumscribed and more specialized than those from which he is excused. This is an immensely complex problem and one which only the entire university can hope to solve. As Sir Eric Ashby has so forcefully reminded us, it will not do for us "to plume ourselves upon our liberality when we stick a few bits of the humanities on the outside of the fabric of science and technology."² What is required is nothing less than "making specialist studies (whatever they are: metallurgy, or dentistry, or Norse philology) the core around which are grouped liberal studies which are *relevant* to these specialist studies. But they must be relevant; the path to culture should be through a man's specialism, not by-passing it."³

Ashby suggests what he has in mind with this interesting example: "Suppose a student decides to take up the study of brewing: his way to acquire general culture is not by diluting his brewing courses with popular lectures on architecture, social history, and ethics, but by making brewing the core of his studies. The *sine qua non* for a man who desires to be cultured is a deep and enduring enthusiasm to do one thing excellently. So there must first of all be an assurance that the student genuinely wants to make beer. From this it is a natural step to the study of biology, microbiology, and chemistry: all subjects which can be studied not as techniques to be practised but as ideas to be understood. As his studies gain momentum the student could, by skilful teaching, be made interested in the economics of marketing beer, in public-houses, in their design, in architecture; or in the history of beer-drinking from the time of the early Egyptian inscriptions, and so in social history: or, in the unhappy moral effects of drinking too much beer, and so in religion and ethics. A student who can weave his technology into the fabric of society can claim to have a liberal education; a student who cannot weave his technology into the fabric of society cannot claim even to be a good technologist."⁴

I think you will agree that this illustration is a little far-fetched. Because Falstaff is pretty good with a tankard of ale is not sufficient reason, in my judgment, to assign our brewery student the two parts of *Henry IV* instead of *Hamlet* and *Othello*. But I think it admirably gets at the kind of thing with which not only professional faculties, but the entire university must come to grips. This will not be easily done; it may even require a kind of minor intellectual revolution. But it will never be done until the professional educator commits himself to its importance and, with all the articulation and grace he

² Sir Eric Ashby, *Technology and the Academics* (Macmillan & Co. Ltd., New York, 1958), p. 81.

³ *Ibid.*, p. 84.

⁴ *Ibid.*, p. 84-85.

can muster, attempts to convince his humanist colleagues to meet him half-way. Thus far, I believe, an effort of this kind has not been made. And you can be certain that I haven't the temerity to try, this evening, to describe how it *can* be made. But I am convinced that it must be, that without it, or something like it, the university will slowly lose its relevance and thus its immense influence over the development of men and society.

In this respect I think we can find some cause for optimism. "The social institution which we call a university has endured now for seven centuries. It could have been destroyed, either by resisting pressure to change and so losing its viability, or by yielding too readily to change and so losing its integrity. But it has survived by adapting itself to the scientific revolution without abdicating its traditional function in society.⁵" It now must adapt itself to the claims of the generalist and the demands of specialization. And this, I feel confident, it will do . . . and in doing it will preserve for the society which supports it, that dedication to truth, that reverence for the past and that commitment to the future, without which society cannot hope to prosper.

⁵ *Ibid.*, p. 97.

Reaching Toward Our Future

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A dean who would be a prophet on his own campus has ample biblical warning of the reception to expect. Prophecy must foretell change or it is false. And if it does so, is unpopular because it is upsetting to the status quo. Hence, planners are often accused of being visionary, yet "without vision the people perish." As Confucius subtly expressed it—"If a man take no thought about what is distant, he will find sorrow near at hand."

Nothing challenges a man's ability more than planning for an uncertain future. It is wise to approach it with due humility and a minimum of dogmatism.

Planning implies some human capacity to weigh the happenings of the day, separating those that are vestiges of a receding past from the portents of an unfolding future. Most of all, however, planning deals with goals—with what is significant and good for family, corporation, college, or country. Rarely is the planner faced with a single choice between good and evil or between the right road and the wrong road. Usually he is faced with many potential opportunities to attain desirable goals. His task is to select the most feasible path to pursue. In doing so, he will give careful thought to the resources he may employ to influence what the future will be.

Planning starts with where we are and the road by which we have traveled. It must also consider the direction of this road and the momentum attained as well as the goals for the future.

State University College of Forestry at Syracuse University has a past replete with distinguished service. The broad scope of its activities were set forth during its first decade. It was decided that it should engage in education at technician, full professional, and graduate level in forestry. It was recognized that public information and research should be important functions. The College boldly ventured into fields then thought to lie outside of forestry—city and park forestry which over the years developed into landscape architecture; wood technology and forest utilization which have developed into wood products engineering; wood distillation that formed the base for the College programs in chemistry and pulp and paper technology.

Always the faculty and administration had in mind that it was educating young men for useful lives as well as professional service; hence, breadth as well as depth in instruction was emphasized.

The early struggle for survival and recognition in a competitive fiscal and professional environment tempered both faculty and students. It stimulated a strong *esprit de corps*. Thus, the College achieved momentum.

It was strongly supported during these days by the Chancellor of Syracuse University and by the College trustees. To these men and their successors the College owes much. The breadth of the statute founding and continuing the College was worked out under their guidance. Certain words of this document merit repeating because it established the framework for past and present planning:

§ 6002. OBJECTS AND PURPOSES. Such college shall have for its objects and purposes: 1. The teaching and instruction of its students in the science and practice of forestry and its several branches, including municipal and landscape forestry, forest engineering and surveying, botany, zoology, entomology, ichthyology, silviculture, forest pathology, wood preservation, utilization and distillation and the manufacture and marketing of forest products.

2. The carrying on and promotion of investigations, experiments and research in forestry and its several branches in field and forest, class room and laboratory and in industrial and commercial plants, also like investigations, experiments and research in relation to the habits, life histories, methods of propagation and management of fish, birds, game, food and fur-bearing animals and forest wild life.

3. The conduct upon land acquired by purchase, gift or lease for such purpose, and otherwise of such experiments in forestation, reforestation, the development of forests for public, commercial and recreational purposes, the protection of water courses and subterranean waterflow, the protection and propagation of the animal life of the forest and forest waters, and, generally, the giving of popular instruction and information concerning the elements of forestry, the effective marketing of forest products and of practical tree-planting throughout the state, as the board of trustees shall deem most advantageous to the interests of the state and the advancement of the science of forestry.

4. The planting, raising, cutting and selling of trees and timber at such times, of such species, and quantities and in such manner as the board of trustees deems best with a view of obtaining and imparting knowledge concerning the scientific management and use of forests, their regulation and administration, and the production, harvesting and reproduction of forest crops and the earning of revenue therefrom.

The College met its major test for survival when the State let the contract for constructing the first College building, Bray Hall. Thereafter, the College felt secure in developing its long-range educational and research objectives.

Now, in its fiftieth year, with properties and plant valued at 12 million dollars, with an annual budget of 2.7 million, with a faculty and research staff of 115, a student enrollment of 765, the College has fulfilled in good measure the hopes and dreams of its founders. Its 176 graduate students include 68 from 23 countries other than our own. Through the Empire State Paper Research Associates it draws support for research from fourteen foreign corporations representing

eight nations and three continents. Through the International Cooperation Administration, the College has four faculty members assigned to the College of Forestry in the Philippines. The College has the understanding support of the trustees and administration of State University of New York that provide countless services and general supervision over College affairs. Certainly, the College has come a long way since 1911, when its appropriation was but \$15,000.

To outsiders it may seem to have arrived. But no faculty member would agree. What we are doing today is but a fraction of what the faculty feels needs to be done and can be done to use our forest resources better, and to provide better education for forestry students.

As the College looks ahead to the next fifty years, it sees our population expanding, our standards of living rising, our demands for education increasing, and our need for forest products and services multiplying. It expects our nation to continue to play a leading role in world affairs that will involve us in concern for forestry in other lands as well as our own. If the forests of the world are to be wisely handled and their products processed to meet growing human needs, foresters of all levels and types will be needed. We will need technicians to handle the routine work that lies beyond the competence of skilled workmen. We will need land managers to give professional direction to developing the timber, water, wildlife, forage, and recreational resources of forests so as to maximize income and total human satisfaction. We will need imaginative designers to plan the landscape for the best possible use by a population ever increasing in density. Staff specialists will be needed in silviculture, tree improvement, protection of forests against destructive insects and diseases. Zoologists, hydrologists, forest statisticians, and many others must back up the work of the land manager. Even greater need is expected for men who can bring professional skills to the forest products industries—pulp and paper, lumber, plywood, furniture, and related wood-processing activities. Research men also will be needed in greatly increased numbers for no major human activity can expect to maintain its position in our highly competitive economy without a continuous flow of new information, ideas, processes, and products. Most of all, we shall need teachers for technical schools, forestry colleges, and, especially, graduate schools. For we must educate not only our own teachers and research workers but many for other lands as well.

Our nation has seen a tremendous increase in the productivity of labor during the past fifty years. This has been true on both farm and in factory. In large measure, this increased output is due to increased use of power-driven machinery and new development resulting from research. The forest products industries generally, though quick to adapt new machines, have lagged in research. Even in New York State we spend in proportion to contributions to State income but 40 per cent as much for education and research in forestry as in agriculture.

Forestry appears to be poised at the frontier of many new research fields of potentially high significance. Break-throughs seem imminent in tree improvement and genetics; tree nutrition; soil fauna and their relation to soil productivity;

systemics applied to disease and insect control; antibiotics in relation to ecology and tree health; tree physiology as it bears on maximum use of soil space, water and solar energy in cellulose production; biochemistry as it relates to tree growth and decay of wood, forest management for water infiltration, and water yield; the ultramicroscopic structure of wood and its influence on timber physics, timber mechanics, pulp qualities and papermaking; graft polymers with cellulose and lignin that may permit tailoring those molecules for specific new purposes. These and other new fields are beckoning tomorrow's forest scientists. To open up these new fields forest scientists will require fundamental knowledge in physics, chemistry, statistics, and engineering science as well as in biology, economics and management.

As we reach toward our future, we see a growing need for educated men in all fields of College activity. We need more pulp and paper technologists because of the growing uses of paper products and of the increasing technologic complexity of specialized processes and uses. We need imaginative engineers and designers to keep wood, an aesthetically pleasing product, competitive and satisfying in light construction, home and office interiors, furniture and a host of other uses. We need landscape architects to plan man's use of land so that industrial, commercial and residential areas may be functional, pleasing, adjusted to modern transportation and interspersed with appropriate parks and recreational areas. We need multiple use forest managers who can adjust timber, water, wildlife and recreation use to land capability.

NEW ACADEMIC DEMANDS

The College must be prepared to do two things—have more specialization and also more generalization. Academically, the College has gone through a marked transformation since 1945. Emphasis has shifted from vocational to professional education, from instruction in current practices to teaching of basic principles, and from largely an undergraduate college to a college with a strong program of graduate study and research. Modern technology necessarily becomes daily more complex and more pervasive.

The College needs more students, better students, more intensive education, more graduate work, more faculties, more laboratories, more elaborate equipment, and more research in the decades ahead than we have today.

NEW GOALS

But a college looking to its future, must think in terms that go beyond numbers of students, breadth of educational offerings, and intensity of study. It needs to think in terms of the human goals. Education deals with finding vigorous minds and calling forth their innate abilities and capacities. It seeks to inspire young people to high levels of achievement, and it seeks to help youth to set goals in life worthy of themselves as individuals. Only by so doing can they be true to themselves. We especially need to discover early the superior student and develop him to the highest degree possible for outstanding service as scientist,

administrator, or professional worker. Humans who reach for the stars never had greater expectation for success than today. People of all lands are realizing that man has vastly greater potentials for creativity than he has so far attained. Man is destined to "roam with a hungry heart." What he is able to discover is but a gateway leading further into the unknown. Aristotle phrased it succinctly in "It is man's nature to desire to know." It was this desire that inspired the building of colleges and universities. It was this spirit that guided our own leaders during the post-Revolutionary period to establish in our land a government where man could be free to develop his talents to the utmost.

Today our college extends its influence beyond the limits of our city, our state, and our nation to draw in people from throughout the world. We must somehow catch the imagination of mankind of many places—not to perpetuate the status quo, not to oppose any particular ideology but, rather, to awaken the desire to know, and, in knowing, the will to be free.

Accent on Quality

WILLIAM P. TOLLEY
Chancellor
Syracuse University

It is always a pleasure and privilege to participate in the celebration of an anniversary of an institution that has a distinguished record of public service and its own personal record of emphasis upon excellence. The first school of forestry, so far as we know, was organized in Saxony in 1811, one hundred and fifty years ago. However, we are here to celebrate the fiftieth anniversary of the New York State College of Forestry at Syracuse University. While it is not the oldest College of Forestry in the world or even in America, in its mere half century of existence it has already taken a place of leadership among the very best.

This is a source of deep pride as we celebrate the Golden Anniversary of the College of Forestry. It is now time to remind ourselves of the counsel of the great German poet Goethe: "What you have inherited from your fathers earn again for yourselves or it will not be yours."

It is deceptive to assume that an accent on quality is self-sustaining or that its maintenance is automatic. The burgeoning of applications for admission and the focusing of public attention upon higher education may make it seem that quality will come naturally. The fact is that it will require everywhere a very vigorous effort, clear understanding, and thorough commitment.

As enrollments double nationally from three million currently enrolled in higher educational institutions to six million, we must bear in mind that this increase is not solely due to the birth rate. There is also an increase in the percentage of high school graduates seeking higher education. It has gone up about 10 per cent each decade and shows no sign of abating. Unfortunately, the motives behind this are not necessarily those that will produce excellence. Social and economic forces still outweigh intellectual curiosity. We have not yet succeeded in either identifying or motivating the most gifted young people.

An equally serious problem affecting an accent on quality is the increasing shortage of thoroughly trained faculty members. It has been estimated by the National Education Association, the United States Office of Education, and the Carnegie Corporation that we may need as many as 450,000 new teachers in higher education by 1970 in order to replace those who leave or are retired and to meet the expanding educational opportunities provided throughout the nation. During this decade it is estimated that we will produce in all fields only about 150,000 Ph.D.'s even allowing for the slowly increasing rate in the numbers so prepared. Less than 50 per cent of those earning the Ph.D. degree now enter teaching as a career. Bernard Berelson, Director of the Bureau of Applied Social Research at Columbia University, points out, "Today the single organization in this country

that employs the most Ph.D.'s is not Harvard, Yale, or Illinois or Michigan. It is du Pont. Furthermore, General Electric has more than twice as many Ph.D.'s on its staff as Princeton, Shell has more than M.I.T., Union Carbide or Eastman or I.B.M. have about as many as Northwestern or California Tech. Such industrial firms employ more Ph.D.'s than all the liberal arts colleges put together and the Federal Government has about as many as the top ten universities put together." Among those who do enter college teaching the majority will gravitate toward those institutions with graduate programs and opportunities for research. It is likely in the next decade that less than 20 per cent will enter undergraduate teaching. It is to be hoped that colleges of forestry, sensitive as they are to the problems of conservation, will develop ways and means of avoiding this attrition at the crucial point of the creation of quality.

The explosion of knowledge that is occurring as an increasingly unmanageable chain reaction poses another threat to the maintenance of quality. It calls for statesmanship and vision in the re-examination of curricula. The distinguished report of The Rockefeller Brothers Foundation entitled, *The Pursuit of Excellence*, calls our attention to the fact that we must "educate our young people for an unknown need." There is a constant threat within education that it will be education for obsolescence. Margaret Mead, the distinguished anthropologist, has pointed out that "no one will live all his life in the world into which he was born, and no one will die in the world in which he worked in his maturity." We cannot accomplish our educational task merely by keeping children and young adults in school longer, we must provide a quality of education that is truly creative, together with opportunities for continuing education throughout life.

In the light of what I have thus far said, it should be clear that while we are celebrating the Golden Anniversary of the College of Forestry, we dare not regard it as the golden age. That is in the future. You know far better than I do the changes that have taken place in forestry over the past fifty years. You know the advance in silviculture, in wood utilization, in paper chemistry, and in the new world of polymers. Whether we turn to the problems of park management, landscape architecture, conservation, land use planning, nursery practices, public administration, the training of men for private business, or to new horizons of resins, plywoods, laminated wood, pressed wood, light construction, paper and plastics, we see wonders being wrought. Who in 1911 would have dreamed we would be debarking and pulping hard woods—a contribution of this college, that we would find uses for branch wood and top-lopings, that we would make sugar and alcohol from sawdust and waste forest products? Who would have foreseen the revolution in packaging and containers? Who among the handful interested in soil conservation would have dreamed up the program of soil conservation districts launched by the Federal Government during World War II or would have thought it could be so "taken-for-granted" today? Who would have expected that a great lumber company like Weyerhaeuser would be exercising national leadership in the intelligent use of forests and other natural resources? Who would have foreseen the profound impact of world forestry through the

Food and Agricultural Organization of the United Nations? Who would have expected that the graduates of our forestry schools would more and more become the leaders in all the industries using forest products?

We have a right to rub our eyes. We have a duty to give thanks. There is a lesson here also. The lesson is that education is not an expense but an investment. It is the wisest investment an individual or a state can make. The dollars invested in the New York State College of Forestry at Syracuse University have been returned a hundred fold in the past fifty years.

Forestry is still a young, vigorous and expanding field. Those who succeed in it will be those distinguished, as in all sciences, by an unusual capacity to dream, a dogged persistence in pursuit of truth, and a ready adaptability to the empirically verified facts. Foresters know the truth stated by Francis Bacon long ago, "We cannot command nature except by obeying her."

The command of nature has brought us an abundance of material wealth. Throughout our world there is a growing faith in this power of education. Without resources beyond subsistence freedom remains an abstraction.

Following the ceremony inducting him into office, the new United States Commissioner of Education, Dr. Sterling M. McMurrin, issued a public statement. Having placed his accent on quality he concluded—"Education is the road to cultural enrichment, to intercultural communication, to worldwide understanding. Most important, education is the road to genuine freedom—the freedom and dignity of the individual."

In its first fifty years the College of Forestry, set in the midst of the life of a great University, has kept its accent on quality. It has played a vital part in the life of our state and our nation in science, industry, recreation, and government.

Across the next fifty years I am confident it will go on to bring an ever richer harvest of wealth, dignity, and freedom to our world.

PART THREE

CHALLENGES IN THE USE OF
FOREST RESOURCES

1880-1881

1881-1882

1882-1883

1883-1884

Challenges in Forest Land Use

RICHARD E. MCARDLE

Chief, Forest Service

United States Department of Agriculture

On this, the Fiftieth Anniversary Celebration of the State University College of Forestry at Syracuse University, I am honored to address you.

I praise the founders of this College of Forestry for their foresight so many years ago. I respect its students, past and present. I applaud the faculty for building a distinguished institution of higher learning, with well-recognized standards of excellence.

Yours is one of the oldest forestry schools in the United States. But age in itself is no assurance of quality. Nor does a superb physical plant guarantee high standards of instruction.

The faculty provides the key to quality. Individually and collectively, their zest, their vision, their maturity, their experience, their ability to stimulate young men, and perhaps most of all, their possession of those virtues which in total we call character—these are the ingredients of excellence.

I do not mention technical competence. This you are assumed to have.

Why do I stress these points? Because to meet the challenges—that is to say, to make the most of the opportunities for wise land use, and to deal effectively with the competition—for forest land use in the future we must rely heavily on the foresters being trained today.

And so I feel that many of the "challenges" we are to talk about are directed primarily to the faculty of this College of Forestry. These are challenges to make your plans wisely, to maintain your excellent standards of instruction, and to stimulate the young men who come under your influence in their formative years for as long as you enjoy that privilege.

This is why, although the topic assigned to me is "Future Challenges in Forest Land Use," I give my comments a subtitle: "Make No Little Plans."

Your founding date, 1911, is a long time ago. I do not object to taking an occasional backward look. But as President Kennedy said in his Inaugural Address, "The world is very different now." We must accept conditions as they are now, not as they may have been. And we must look ahead another half century to a world even more different than our world of today. The challenges of forest land use are not those of years past but of today and the years ahead.

"From the beginning of civilization, every nation's basic wealth and progress has stemmed in large measure from its natural resources. This Nation has been, and is now, especially fortunate in the blessings we have inherited. Our entire society rests upon—and is dependent upon—our water, our

land, our forests, and our minerals. How we use these resources influences our health, security, economy, and well being.

"But if we fail to chart the proper course of conservation and development—if we fail to use these blessings prudently—we will be in trouble within a short time."

Here in a few words from the President's recent message to Congress on natural resources is the challenge of our times to those of us whose life work is management of natural resources.

Imagine that you are looking at a map of our country. Here is all the land we have. Since we are not an aggressor nation, this is all the land we are likely ever to have. From this land we must obtain almost all our food, our clothing, our shelter, the fuel to warm that shelter and to cook our food. From this land we must in addition obtain the raw materials of industry to manufacture those things that make life more pleasant, more than mere existence. Except for the seas around us there is no other place to obtain these basic necessities of life.

By the end of this century—a short four decades away—our country will have twice as many people as we have today. There will be twice as many stomachs to fill, twice as many bodies to clothe, shelter, and warm. We shall need more of everything—more food, fiber, timber, water, minerals, energy, fuels, outdoor recreation—more of everything that in large part can be had only from land.

All of these greatly increased needs must be met from the same total area of land that we have today.

Actually, we shall have less land from which to obtain these necessities of life. Productive land—land capable of producing food, fuel, shelter, clothing, and raw materials for industry—increasingly is being diverted to other uses: to superhighways, airports, urban development, for national defense, to name only a few. Every acre so diverted throws just that much more burden on the remaining acres.

Unfortunately, too, not all of our land is capable of producing these necessities of life. We have many millions of acres of desert and low-quality land, more millions of acres too high, too cold, too rocky, or too wet to justify inclusion in our productive base. We cannot afford to think only in terms of total acres. We must focus our attention on productive acres.

We speak of challenges as the central theme of our discussions. Yet I do not care for the word, with its implication of a summons to a contest. The only contest is to overcome our own inertia.

We are a peace-loving and proud people, blessed by a bountiful nature and pledged to high standards. In natural resources, as in other resources, we are not weak; and we need not be insecure. With renewed effort and with public attention, we shall assure an abundance of natural resources for America, and with this abundance our civilization will prosper.

In the few years that I have been Chief of the Forest Service, I have given more than half a hundred major talks. The theme of many of these has been directed toward the future. To name a few: "Opportunities and Goals for Forest

Management," "Trends in Forestry in the South," "Timber Resources for America's Future," "Timber on the Horizon," "Water, Forests and People," "The Sixties—Decade of Decision," "Horizons Unlimited," and so on.

Why have these talks been so oriented? I have hoped in my small way to stir the public's imagination, to stimulate our forest scientists, to give encouragement and strength to the forest industries, to impart some knowledge to our students, and to create confidence in the public service. This has been my personal challenge—one of faith and leadership.

Today we are assembled at this Fiftieth Anniversary Celebration to hear eminent men talk about forest resources, forest production, new wood uses, fibers and molecules, and forestry education. It is my earnest hope that in these discussions we will throw off the bonds of conservatism, escape the shackles of tradition, and explore in a broader spectrum than usually occurs when professionals talk with fellow professionals about conservation of natural resources.

Let us consider water for a moment. Water is one of the most valuable products of forest lands. In large measure the challenges, the opportunities, for wise use of forest lands reflect our opportunities for obtaining adequate supplies of usable water. We foresters have been indoctrinated in the merits of erosion- and flood control through protection of upstream watersheds. Only of late has our thinking turned to watershed management in the sense of affecting in a positive manner the yield, the quantity, of water. We have in the past been concerned mainly with the quality of water, which is a product of watershed protection, and but little with quantity, which is the end result of watershed management. We are going to have to think more and more about quantity of water as well as quality.

In many places water is becoming the chief limiting factor in further urban and industrial expansion. Our cities are reaching out further and further, sometimes for hundreds of miles, to obtain increased supplies of water. The conversion of salt water to fresh is being endlessly explored, and some day science will make this process both practical and economical.

What effect will such discoveries have on the need to adjust land uses to water needs? As a practical matter, how far inland may converted sea water be transported? In what manner and to what degree will this possibility of the future affect today our long-range planning for forested lands, and especially our priorities for forest land use?

This is the kind of land-use problem that poses a challenge to the ingenuity of our scientists and should shake us foresters out of our classic patterns of thinking.

I'll give you another example. Forest recreation is the idol of the moment. It has the attention of legislators, of State and local governments, of study commissions, and of universities. People are flocking to the out-of-doors in unprecedented numbers. Why?

The influx is more than can be explained simply by population expansion. Is the phenomenon that we are experiencing a passing fad, or is it the beginning of something much more permanent?

I think a significant factor could well be that in our free society the low and middle-income groups have begun to find a new source of spiritual fulfillment hitherto available primarily to the well-to-do. The usual explanations are the prosaic ones of better roads, the automobile, and more leisure time. But perhaps there are other more fundamental reasons such as higher costs of more luxurious types of recreation. There is also the undeniable fact that the middle-income segment of our population is becoming a larger and larger proportion of the total.

Half a century ago we were mainly a rural people. Today the situation is exactly reversed and we have become a nation of city dwellers. In the ever-growing competition for use of forest land is it not logical that we ask ourselves if a preponderance of city dwellers doesn't mean that outdoor recreation—some way to escape the pressures of crowded living—has also become one of the necessities of life?

Should the great popularity of outdoor recreation continue, and I think it will, there will be posed real problems of competition for forest land use, of programming, of multiple-use land management, of financing, including cost-sharing by the beneficiaries, and questions of institutional responsibility. These problems will test the skills of administrators and the wisdom of policy makers. Again—a challenge for wise use of natural resources and especially of forest resources.

This ever-growing competition for land is going to make foresters adjust their traditional thinking. We see everywhere great urban expansions—communities pushing back the forest in the same way but on a vastly larger scale than happened three hundred years ago when our forefathers settled this country. A huge ten-year highway program is under way. Transmission lines for electrical power, for oil and gas, are spreading across the land. Despite the promise of saline water conversion we can expect continued large withdrawals of forest land for reservoirs of all kinds.

Land will continue to be needed for national defense, for atomic energy, and similar purposes.

There are tremendous pressures to set aside timberlands for parks or other specialized recreational use. One estimate forecasts an increase in forest land used as parks and wildlife refuges from about twenty-seven to forty-seven million acres by the year 2000. Another recent proposal is an increase to more than sixty million acres in less than ten years. I do not know which estimate is more nearly correct. I do know that this is a use of forest land which must have our serious consideration.

There is still another kind of competition for forest land that many of you may not have thought about. This is the prospective need of forest land to grow food crops. It may seem ironic to talk about needing more land for food production when today we have large surpluses of some agricultural crops. Actually, most of the experts dealing with this subject do not forecast any substantial change in total acreage devoted to production of food crops, at least not for the next fifteen to twenty years. The increases we shall need in the next couple of decades can be obtained through widespread application of better management,

increased use of fertilizers, improvement in plant varieties, and other technological advances.

Although some predictions are that by the end of the century as much as seventy-three million acres of forest land may be diverted to food-crop production, the probabilities are that the total diversion of forest land to food crops will be less. A more significant change and one much more certain is diversion of the best, the most productive forest land to food crops. The better land will go into food crops and the poorer land into forests. The net effect on timber production will be substantial.

In total, the possible further diversion of forest lands for urban development, parks, reservoirs, food production, and so on could mean that one-fourth of our commercial forest land, equal to one-third of our timber-growing capacity, may seriously be sought for other purposes within the next few decades.

National policy on these competitive needs for forest land may very likely be determined for the most part fairly soon. The outcome of these issues cannot fail to have a significant long-range effect on forestry and forest-land use. This is one of the destiny decisions of our times. Call it a challenge if you wish.

The competition for forest land inevitably brings with it an ever-growing need for greater intensity of management. This is why the Forest Service subscribes so heartily to multiple use as the best practice of management for most of the publicly owned forest lands in the United States.

Multiple use helps to overcome problems of scarcity. It tends to reduce or resolve conflicts of interest and competition for resources. It promotes balance in resource use. It impedes the ascendancy of single-interest pressures. Properly applied, multiple use involves consideration of both aesthetic and economic criteria in arriving at management decisions. It offers balance between materialistic and nonmaterialistic values.

Multiple use is being extended in varying degree to other public and to privately owned forest lands, mainly those in the larger ownerships. A major policy question of our time is to what extent Federal and State educational, technical, and other assistance programs should encourage multiple use on the smaller forest ownerships.

Heretofore, public stimuli focused on such lands have been directed primarily to growing more and better timber. Nowadays foresters need to think in broader terms.

Concepts of forestry by foresters urgently need to be broadened. Failure to do so will continue to exclude foresters from many of the policy decisions of today that affect the use of forest land for the tomorrows. Now, as in the past, I firmly believe that most such policy decisions are made not by foresters, but by legislators, executives, financiers, engineers, and men of other disciplines and orientation. If ever there is a challenge to foresters, it is to escape from narrow technocracy and to engage actively in the practice of political science and business management.

Another of forestry's greatest handicaps is the difficulty of attracting public notice. In part, this is because foresters must deal largely in terms of a distant future. Problems of immediacy get the attention and the money. Problems of the future compete poorly. But compete we must.

To compete effectively we must make the public understand its dependence on forests. This is another of the great challenges in natural resources—the competition for public understanding.

Let me pause for a moment to explain what I mean by "the public" and to examine its vital connection to leadership.

The public in my opinion is that nebulous body which is everybody. The public most often makes its will felt negatively in what it will not tolerate. Rarely does the public provide leadership for affirmative and creative action; but it does respond to leadership from its officers who have the means to know and the responsibility and competence to lead. It would be brash indeed, for example, to assume that the public really understands the technical facts of atomic energy, the treatment of cancer, the essentiality of water, or the details of forestry and therefore will develop the programs needed in the public interest. Public opinion, if uninspired, uninformed, and undirected by responsible and conscientious leaders, can drift toward what is not good for the Nation.

To those of us who serve the public that is everybody, I say let us always be willing to discuss, but let us never hesitate to lead. Leadership, too, is one of our major challenges, one that should not, must not, be dodged.

I call your attention to one more challenge in use of land for forestry purposes. Our institutional arrangements for forestry are certain to be reassessed from time to time. I mean our system of National and State Forests, and the balance between public and private forest land. The pattern of forestry responsibility between State and Federal Governments is quite different in the United States than among our Canadian neighbors to the North and among many other countries. Assignment of responsibility within a given level of government for the management of certain lands or for functional responsibilities is likewise subject to periodic reassessment.

The established pattern of private forest land ownership with three-fourths of all privately owned forest land split into millions of small holdings is an accepted pattern in this country, but recognized as unfavorable to the practice of forestry. What, if anything, should and can be done to overcome the problem of smallness?

In summation, I have tried to tell you what to me are some of the imposing problems that we must solve if our people are to have resources for the future. Among them are how to compete for public attention and all that goes with it; how to double our water yield and triple our power capacity in the next twenty years; how to control water and air pollution and convert salt water to fresh; how to accommodate great increases in needs for both outdoor recreation and timber; how to provide leadership to our people, impart knowledge to our youth, and stimulate our scientists; how to meet immensely stiffer competition for land

and space; how to best arrange our institutional patterns in order to serve our people well; how to think creatively; how to shake the bonds of tradition and to plan wisely; and last but not least, how our profession can engage effectively in shaping the policies of today that in turn mold the framework of tomorrow.

These are not problems or "challenges" of mere academic interest. These are problems that must be solved if we as a people expect to live well, perhaps to live at all. These are urgent problems and they are big problems. We must make plans big enough to fit these needs. I leave with you these words of Daniel Burnham:

"Make no little plans; they have no magic to stir men's blood and probably themselves will not be realized. Make big plans. Aim high in hope and work, remembering that a noble logical diagram once recorded will never die, but long after we are gone will be a living thing asserting itself with ever-growing insistency."

Future Demands for Recreation and Space

LAURANCE S. ROCKEFELLER

Chairman

Outdoor Recreation Resources Review Commission

I would like to say how pleased I am to take part in this discussion under the chairmanship of Director Conrad Wirth. As the head of the National Park Service, he has shown an unusual ability to get things done consistent with the Park Law safeguarding our heritage of nature and wildlife for the enjoyment of future generations. His objectivity and factual approach serve him well in his job.

My assignment today provides an opportunity to make a most encouraging report. And in connection with it, I would like to pay tribute to the people and leaders of New York State—the ones who have made this report possible.

The State Commissioner of Conservation, Harold Wilm; the President of the State Council of Parks, Robert Moses; and the Governor, my brother Nelson, worked together in developing the \$75,000,000 bond issue program for acquisition of new park and recreation lands. The people of New York clearly understood the need for action before the lands were swallowed up for other uses. They voted nearly four to one in favor of the program.

It now appears that New York State is not the only beneficiary. The big vote in favor of the bond issue is having profound and significant effects outside the State.

The vote demonstrated that people see the need for more outdoor recreation places, they want them, are prepared to support sound programs that will provide them and, what's most important, are willing to pay for them. The margin of victory here in New York changed the minds of many public officials across the country who had felt that providing funds for outdoor recreation was not a popular cause.

Bond issues and other measures for outdoor recreation now are being proposed in other states: California, Maryland, New Jersey, Utah, and Wisconsin, among others. These developments undoubtedly are being followed with deep interest by the Kennedy administration and members of Congress.

All these indications of popular support have given heart to the leaders in the campaign for more outdoor recreation facilities. They give new meaning to the President's commendable emphasis on physical fitness, which has already stirred the American people. The two programs—outdoor recreation and physical fitness—dovetail perfectly. And I am happy to say that the precedent set by New York last fall will also add greatly to the prospects for implementing the recommendations which the Outdoor Recreation Resources Review Commission will be making some months from now.

RECREATION DEMANDS WILL CONTINUE TO INCREASE

My assignment is to deal with the subject of future demand for outdoor recreation and the space required to meet that demand, and the challenge this represents in the use of our forest resources.

There are great pressures on neighborhood and day-use outdoor recreation places. The supply of them is short and growing shorter in and around urban areas where most of the American people live. There also are pressures for longer stays in mountain areas, forests, at seashores and other beach and water areas. And future needs will require opening up more of them to recreation.

Basic social and economic forces will certainly increase these pressures on outdoor space for recreation. Increasing demand must inevitably come from a growing population with greater personal income and mobility, and somewhat more leisure time.

With the anticipated growth in population, even a modest increase in free time will step up the pressures for outdoor recreation enormously.

Nothing short of catastrophe could alter the nation's growth in people and their ability to earn more by means of more efficient production machines. As for mobility, which determines where we go and how fast we get there, the future seems to promise great things—at least for everyone but commuters in our metropolitan areas. There also is agreement that time for leisure will increase over the next several decades—although by how much is a big question.

While long-range forecasting about leisure is understandably risky, carefully drawn estimates indicate a modest rise in free time for the wage earner. For example, a California study looking ahead to 1980 projects that his leisure time will increase by about four and one-half hours per week in that state. This contrasts with speculation which has the work week cut in half.

Recreation demand on our public and private forests reflects the general surge toward outdoor recreation by the American people. It presents its own complex of problems because the activities occur in woodlands which must also support other functions. And some special problems involving management and facilities exist because a sizable proportion of the visitors remains within the forests for a week or more.

Despite the special problems, our forests are part and parcel of our open space resources.

To the four factors I have mentioned—population, income, mobility and leisure time—can be added another important one: Man's inherent need for open space. The spread of urbanization (surely a mixed blessing, to say the least) accentuates man's spiritual need of the outdoors. Urban man, if he is to be healthy, must develop what Luther Gulick has summed up as an awareness of "his relationship to the world of nature."

This awareness is important in itself, for it can help gain the support necessary to transform the need for recreation places into programs, public and private, that will provide for those needs. The best illustration of this is the overwhelming

approval of the park and recreation lands bond issue last November. The citizens of New York State were very much aware of the needs.

FOREST RECREATION AND MULTIPLE USE

Forest areas are experiencing a great increase in recreation use. And all signs point to more of the same since the forests, and the streams and lakes within them, are prime places for hunting, fishing, swimming, boating, hiking, camping, skiing, picnicking, sightseeing and quiet contemplation.

There is a fact of key importance which a U.S. Forest Service expert has summed up in these words:

"Except for hunting, space in forests managed for timber production is little used by recreationists. For this reason these forests provide one of the best areas for expansion of recreation space."

This fact is often submerged by figures which tend to give an impression of rather full recreation use of our forest resources.

Properly handled, forest recreation activities blend with the other functions of woodland. These include the watershed function and timber production, and support of wildlife and grazing. Of course not all of these are compatible at every spot in the forest at the same time. But they can be made compatible by intelligent management. For example, camping and fishing can proceed in one section while timber is being cut in another.

This, of course, is the principle of multiple use in action. Recreation has only recently been officially recognized as one of the multiple uses in our National Forests, although it has been a fact of life for many years. To make recreation an equal partner, the Forest Service is moving to catch up with this demand on its facilities.

State-owned forest lands represent a small segment of our total forest resources although they are an important factor in some states, primarily in the Far West. The uses to which they are put vary from management demonstration work to full-scale multiple use. Certainly pressures will be increasing to expand their recreational role.

In our privately-owned forests, the acceptance of a recreational role is relatively new. Its potential significance is great, particularly in the East and South where public lands are in short supply.

It seems obvious that the practice of multiple use will have to be expanded to meet future demands on our forest. And here I refer to the demands for water, lumber, forage and wildlife cover as well as recreation. Meeting them will require more intensive management, with the conservation measures implicit in such management.

It will also require the development of heretofore neglected forest areas—not the National Parks where lumbering is out-of-bounds, but woodlands which have been somehow overlooked. West Virginia, for example, has many idle forests in private hands whose potential for recreation alone would seem to justify development.

And it will require the good will and cooperation of all interested parties: Water users, commercial lumbermen, conservation groups, wildlands specialists, the recreation-seeking public, the local, state and federal agencies which are concerned with all the uses.

THE NATIONAL FORESTS AND PRIVATE FORESTS

As I have noted, the National Forest Service now is dedicated to the multiple use principle. Its Operations Multiple Use, already under way, is providing valuable new facilities for recreation as well as improvements in all the other categories of National Forest use.

It is a far-sighted program covering, in one way or another, the National Forests which exist in thirty-nine of our states, including Alaska, and the Commonwealth of Puerto Rico. Together these Forests comprise 181 million acres.

The Forest Service estimates the number of recreation visits will double by 1970, to reach a total of 130 million a year. People will come to picnic, camp, hunt, fish and ski, and—as the Service has said in a poetic moment—“to sit and dream, to be close to the land and the wonderful things of nature.”

The impressive acreage of our National Forests supports more than a third of the nation's big game. In the Forests, also, flow 81,000 miles of streams, and there are more than two million acres of natural lakes and impounded waters serving recreation and other uses.

Out of these same Forests come nine billion board feet of timber a year. The Forest Service hopes to raise the yield over the current decade to at least eleven billion board feet. I would hope that with intelligent management this goal can be reached without upsetting the harmony of Nature or doing violence to those who seek solitude in the woods.

There also are encouraging developments in the private forest sector. The chief forester for the American Forest Products Industries, James G. McClellan, has said: “Use of forest land for recreational purposes is an important part of the multiple-use management program which forest industries are following.”

This represents a notable forward step. It is encouraging to those of us who feel keenly about the importance of outdoor recreation in America's future.

The forest lands to which Mr. McClellan refers total more than sixty-two million acres. According to a survey by the industry association, by far the greater part of them, and the streams within them, are open to the public. While the degree of recreational use varies greatly in these privately-owned forests, the association reports six million recreation visits to them last year.

I would like to quote from a speech on this subject by an official of one of the largest timber companies. He cites the decision by many lumber, pulp and paper companies to accept recreation seekers and make some provision for them. He goes on to say: “This important change in attitude on the part of these companies has developed largely since the war as the result of a tremendous recreation expansion taking place throughout the country.”

He adds: "Companies have found it impossible to keep swarms of recreation seekers off their lands and so have decided to turn what was becoming a tremendous liability because of increasing numbers of fires and vandalism into a public relations asset. To say the least, the new attitude has resulted in developing a tremendous bank of good will on the part of the recreation-using public."

To my mind, this is an enlightened point of view by companies wise enough to face the facts realistically, and with the public interest in mind. And the record seems to show that fire losses and vandalism actually have been reduced on the private lands open to an appreciative public.

THE OUTDOOR RECREATION RESOURCES REVIEW COMMISSION

After hearing this report one might be tempted to say all's right with our recreation prospects as far as the forests are concerned. However, such assurance could be misleading. It's a good start but much more needs to be done. The indications are that both the Forest Service and private companies will be called upon to provide for more recreation seekers than they anticipate. So it appears, anyway, when your responsibility is to gauge the needs of the American people fifteen years from today and at the beginning of the 21st century.

That is what the Outdoor Recreation Resources Review Commission is attempting to do. Congress gave us specific instructions to take the long view, to look as far ahead as the year 2000, as well as at the present. The Commission has the job of finding answers to these basic questions:

- 1—What are the recreation wants and needs of the American people now and what will they be in the years 1976 and 2000?
- 2—What recreation resources does the nation have available to fill those needs?
- 3—What policies and programs should be recommended to insure that the needs of the present and future are adequately and efficiently met?

The Commission expects to find factual answers to questions 1 and 2 in surveys, state-by-state inventories and projections being made for us by experts. These reports are coming in over the next few months. The 15 Commissioners then will develop the recommendations requested by question number three.

Meanwhile, the Commission and its Advisory Council have been discussing many problems including those faced by the forest industries. Members of the Council include representatives of industry, various interested groups and government. I am confident that together we will develop realistic proposals as well as make available a large amount of information useful to federal, state and local governments and to private industry.

PROBLEMS AND OPPORTUNITIES

So far as forest lands are concerned, the Commission undoubtedly will emphasize the need for better utilization on the part of both public and private owners, as a means of meeting both present and future demands for recreation. Carrying out such a program will add to the foresters' problems in conservation and the

costs of management and facilities. It will also create unique opportunities for service.

One of the problems is that the compatibility of recreation with the other woodland functions still is improperly understood. Certain of the Commission's studies deal with this subject. Hopefully, they will point the way to improved operating methods.

Also, it is to be hoped the Commission will develop proposals offering some relief for the costs of establishing and maintaining public recreational facilities in private forests. Recognition of the landowner's costs is necessary if we are going to call upon him to provide what amounts to a public service.

Among the possibilities is the development of a fair system of user fees geared to facilities, such as campsites, boat ramps, children's playgrounds, ski lifts, hiking trails and so on. Tax concessions for certain facilities or land use is another possibility, as it is unlikely that user fees could be kept reasonable and still absorb the expense.

I would like to suggest, too, that there is real benefit to management in providing such facilities. Their very existence steers the visitors to those sections of the woods where the forest manager can exercise the supervision necessary for the good of both the guests and the forest.

The cost of public liability insurance has deterred many private forest owners from providing for extensive recreation use of their lands. It seems reasonable to assume that this problem can be worked out as a public responsibility.

Happily, experience shows that fire dangers and vandalism do not necessarily increase when more people use the woods. Some of the largest companies in the forestry business declare that these threats can in a large measure be offset by a good sound public education program. That the great majority of our people can be educated in this matter has been proved by the success of "Smoky the Bear" and similar campaigns.

Another educational possibility offers an exciting opportunity to public and private forest managers to do more than merely provide space for vacationers. This is to impart their knowledge of the land, the wildlife, and the principles of conservation.

With the great increase in forest recreation, camping areas and hiking trails can serve as natural classrooms for millions of Americans. Conservation, wildlife and other organizations can be enlisted to aid in the support and development of forest-education programs involving such things as outdoor museums and exhibits located in the forests themselves. Vacationers can have their enjoyment multiplied many times by knowledge.

There is a definite need for more forest hiking trails, and better maintenance and maps for trails. I believe our park and forest managers are incorrect when they say the public won't use them, and I expect that careful studies now being made will substantiate my view. In a very real way, hiking trails are a practical aspect of multiple use because they are valuable in fire prevention and fire fighting.

In closing, I would like to emphasize what is, for me, a most important point. Ever-increasing recreation needs should not be cause for dismay. Wise planning and use can meet the problems arising from the demand of the American people for a place in the outdoors. We here, who love and enjoy the outdoors, should welcome the newcomers to the forest. Its benefits can only help to make us a stronger, happier people.

The Future Demand for Wood

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When the subject arises of the future demand for this or that, the talk is apt to turn to the long-discussed upward trend in our population.

CONSUMERS UNLIMITED

Thomas Malthus, who published his *Essay* in 1798, founded a line of pessimists who have taken a dim view of what man, in all his fertility, was doing to the earth, to the balance of nature, and incidentally to himself. Across from Malthus has sprung up the party of optimists, who see population growth as a multiplying, not so much of mouths, as of hands and brains. These optimists are the heralds of the abundant life: the third family car, the indelible advertising slogan, the unpaid bill, the buckling attic, the proper use of leisure time.

It has become fashionable for speakers on demand to pause in their talk and issue a bulletin on the number of new births since they took the rostrum. For long-winded speakers, the number may run into thousands. A professor at Illinois recently computed from trends of the past 2,000 years that human numbers will approach infinity in 2026. Then, man will find Doomsday, not by starvation, but by being squeezed to death. That forecaster, optimist that he is, should not have overlooked the chance that man's bulging cupboards will beat him in the race toward infinity and thus will quietly snuff him out while he and his family, in the ultimate act of togetherness, are studying the TV commercials for new ideas.

If the deluge is to be of goods and services more than of people, then the question of the future demand for wood gains special meaning: With what portion of wood will man in his last hours choose to surround himself? Will he wish to be enfolded in a lumber and plywood home? Perhaps, in deference to the multiple-use idea, he will choose to be smothered in an avalanche of assorted timber, water, forage, wildlife, and recreational services.

In any case, the contents of the fatal cornucopia will surely be fitted to consumers' tastes and preferences. The question, then, of future wood demand requires merely forecasting the likes and dislikes of consumers, who are as uneccentric, unimpulsive, and unenigmatic as may be. The task is the easier if one supposes that wood will have become as well entrenched in advertising as other commodities and that the contending hucksters will be at a standoff. Advertising will, of course, contribute to the affair through its use of wood as paper. Or should we question if paper will still be made from wood in that future time? And should we question what altogether new products, of wood and otherwise, will be competing for the favor of those unlimited consumers?

LIFE IN THE WOODS

Before such issues I propose to retreat after the manner of Henry David Thoreau. I will take to the woods. There I will study future demand from a forester's view: in terms of the *potential timber output*, which sets an effective limit upon demand and is, indeed, the woods counterpart of effective demand. In the long run, how much timber per year can we expect landowners to produce on a continuing basis from young-growth forests? This potential timber output rests on determinants which, though not all readily predictable, are generally more stable and foreseeable than those that govern the consumer's behavior. Broadly speaking, there are just two determinants: the amount and kind of land devoted to timber growing, and the intensity of the timber management.

As for the land given over to timber growing, this is the outcome of competition among land uses: in general, forest as against nonforest uses; and within the forest, the timber use as against uses that exclude timber cutting.

As for timber-management intensity, this the forest owner decides. If he is to make the fullest use of his resources, then his timber management will depend on the values he expects to create and the sacrifices he expects to make in creating them. The values and sacrifices in question are of two quite different kinds.

One kind is the owner's return and cost upon the wood-producing machine: the growing stock of trees, or timber capital. The return is the increase in capital value through growth of wood or a rise in its price or changes in related values such as scenic values and tax changes. The cost is that of holding the capital. This cost arises in the owner's opportunity to liquidate part of his timber and use the resulting funds in some alternative way, as for new investment or for consumption. The alternative rate of return on the funds invested in timber capital therefore measures the cost of holding this capital. Figured net of expenses such as the income tax and adjusted for comparative risk, the alternative rate of return is a guiding rate, fashioned to the owner's circumstances and ready for his use—his explicit or implicit use—in judging the wisdom of any timber investment.

Taken together, the value growth of timber and the owner's guiding rate of return largely determine the quantity and value of timber growing stock that the thinking owner will want to hold and the age and size to which he will want to grow his trees. That is, they largely control his investment in wood-producing plant, which in great measure sets the intensity of his timber management.

However, there is a second kind of value and cost that does have a bearing on the intensity of an owner's practice. This is the prospective price of his timber crop in relation to his expense of production other than holding the timber capital. The expense is mainly that of labor, together with such machines, supplies, and the like as may be used with the labor. Among the timber-management practices that a thinking owner is apt to adjust to the price-expense prospect are forest seeding and planting, soil fertilization, and forest protection from fire and other enemies. The intensity of his protection efforts is of course influenced by his judgment of non-timber as well as timber values of the forest.

The foregoing line of thought relates wood production to certain determinants of land use and timber management. Pursuing this line, I now propose to derive a specific estimate of long-run potential timber output in the United States. The data available to me are in some cases good enough, but in others meager. They are weak as regards the productivity of our forest sites under silviculture. Consequently such value as my analysis may have rests not so much in the results as in the method. The method, as I have pointed out, is to bypass the imponderables of product development and consumer taste and focus upon the discernibles in forest management. I mean to show that in the long run the latter have the overriding influence upon our national timber consumption. And I propose to suggest what items of information are needed for a sensible forecast of consumption.

First I will state my assumptions and predictions. I will not go into the detail of how they were calculated. Then I will talk about what my findings imply for forest policy in the long view and in the short.

POTENTIAL TIMBER OUTPUT

At the time I am speaking of—namely, at the soonest time when a young-growth timber potential could be reached—changes in land use will have taken place. The area of farmed lands will be somewhat smaller than today. Transportation and power developments will take up somewhat more room. The two greatest changes, both amounting to more than a doubling of present acreage, will be in cities and in recreational areas. All such changes considered, less than 450 million acres of land will be available for timber growing, as against today's 490 million acres.

Privately owned commercial forest will be further concentrated in big properties, at the expense mainly of the small nonfarm and the medium-size private holdings. Public ownership will remain largely unchanged except for the effects of reservation for noncommercial use.

Guiding rates of return in timber management will vary widely with forest ownership. Three groups of owners may be distinguished: first, conservative owners, notably the federal government and large corporations, with an average guiding rate of 3 per cent; second, exploitive owners, mainly small private owners, whose guiding rates will average between 12 and 14 per cent; third, intermediate owners such as state and local governments and middle-size private owners, whose rates will be about 6 per cent. The weighted average of the guiding rates for all commercial forests will also be close to 6 per cent.

The federal income tax, despite praiseworthy efforts of reformers, will continue to subsidize private forestry. The general property tax will come to be administered without penalty against forest conservation.

Timber prices, though at times they will have risen relatively to the general price level, will stand without prospect of continuous change in either direction, at an average of about twice the relative prices of recent years. This assumption about the price level will prove to have little bearing on the estimate of potential output.

There will be value premiums upon trees of larger size, primarily because of cost savings in logging, transporting, and processing. In general, these premiums will be such that trees will become merchantable when they reach a breast-high diameter of five inches, and thereafter the value of their merchantable section, extending to a four-inch top, will be proportional to its volume by the International log rule, $\frac{1}{4}$ -inch kerf allowed.

Forestry technology will have advanced so as to reduce costs. New strains of trees will not have been widely introduced, so that there will be no great differences from today's growth rates on this account. However, methods of artificial regeneration and of partial cutting will have been improved to the point that most conservative and intermediate forest owners can afford to use them. Transportation, not necessarily limited to ground systems, and the growth of population will be such as to minimize variations in forest accessibility. Forest protection will be intensified so that non-salvable timber losses will be negligible.

Under the foregoing assumptions, the long-run potential output of merchantable timber in the United States is roughly twenty billion cubic feet per year, expressed in terms of roundwood. One may grasp the meaning of twenty billion cubic feet with the help of a few comparisons. The amount is about 60 per cent greater than our annual consumption in the last few years, including the roundwood equivalent of our imports. On the other hand, it is 25 to 30 per cent less than the "realizable growth" estimated by the United States Forest Service in its most recent national appraisal of the timber situation, the Timber Resource Review. The figure of twenty billion cubic feet underruns (by 10 per cent) the medium projection of "demand" for wood from all sources estimated in the Timber Resource Review for the year 2000. This year is about four decades off—a good bit nearer than the long run of which I am speaking. The comparison perhaps suggests that to "demand" is one matter, but to get what one "demands" is another.

What sort of thing is this timber potential? Does it really represent demand? Is it a goal for forest policy? Is it a goal that can be reached? Is it subject to change?

THE LONG VIEW

To take up the last question first, consider how the consumption limit fixed by the long-run output potential might be bypassed or altered. Suppose we in the United States set out to get more timber than this. What could we do about it?

One measure is to improve the technology of tree growing, as by developing more vigorous strains. A second, already in use, is to import. Both these measures may well have fairly close limits. A third measure, comparatively unlimited, is to increase our substitution of other materials for wood.

A fourth measure for adjusting timber supplies in the long run is to bid timber prices up, relatively to others. Ordinarily this is the way society gets more goods from competitive parts of the economy: Its new demand tends to raise the price of the thing demanded, and the producers respond by increasing their efforts to satisfy demand. However, in the timber-growing game, society's telegraphic signals through the market always reach producers as a garbled message, and the latter

fail to respond as they were meant to. This is because higher demands and timber values, although they increase the returns from timber growing, also increase—about equally—the principal cost of timber growing, the cost of holding timber capital.

It is true that the continuous prospect of a relatively rising timber price will encourage owners to intensify their management. But the prospect implies an actual rise, and for prices to keep going up in the long run would put a decisive penalty on wood use.

It is also true that a consummated increase in the timber-price level may change land use in favor of timber. Moreover, it gives the landowner some incentive to step up his protection effort, improve his site with fertilizer, extend his planting or seeding practice, and the like. And yet the main effect of the higher price is to undermine consumers' interest and to raise land values. A long-run level of timber prices half again as high as the one I assumed would mean an output potential little more than 5 per cent greater than the one I arrived at. And incidentally, much lower prices would similarly make little difference in the potential.

Here I come to the conclusion that since the amount of wood supplied in the long run is so feebly responsive to price, this supply, or potential output, almost alone can determine wood consumption. Demand in relation to price, provided it is great enough to permit consuming the potential timber output at all, is influential only in setting the value of the wood. And so, to a degree, consumers are free to put their own price tag on that quantity of wood which growers, largely ignoring the tag, will provide anyhow.

But is there no such thing for timber as long-run demand of the ordinary sort: a force that consumers can exert to make their wants known in the economy and to get a response from producers? The question suggests a fifth measure for adjusting supplies—that is, to increase the long-run timber-output potential by lowering timber-owners' guiding rates of return. More timber will eventually be grown if heavier growing stocks are carried in the forest, and such stocks can rationally be held if the cost of holding them is lightened. Furthermore, all other steps in forest management that require waiting for returns (and few do not) will be made easier if the guiding rate, which reflects waiting cost, is lowered. And more land may be used for timber growing if guiding rates fall.

The national timber-output potential is responsive to forest owners' guiding rates. If the nationwide average rate were to be 5 per cent, just one percentage lower than I have supposed in my forecast, then the long-run potential timber output would be more than a tenth greater: more than twenty-two billion cubic feet per year. If rates averaged a conservative 3 per cent, the potential would be close to twenty-seven billion cubic feet. And to add a fanciful footnote to these conjectures—if guiding rates were zero, potential output would be above forty billion feet: It would equal the physical maximum within the limit of my other assumptions.

In timber's case, then, the long-run demand that counts is that determined by society when it judges and tries to influence forest owners' guiding rates of return. The rates are our principal means for effectively stating a demand for wood. Whatever the rates deemed appropriate by society, the potential output thus set becomes a goal for forest policy.

There are various ways for the nation to lower guiding rates of return in timber management. For instance, we can swallow our traditional esteem for small-scale land proprietorship and encourage the shifting of forest land from less into more conservative hands, either through outright purchase or through leasing. We can reduce the risks of timber management and marketing, as through research to replace speculation with facts. We can, in effect, reduce guiding rates by means of regulation or subsidy—but here it should be noted that beyond a point we would be forcing overinvestment in forests by comparison with other resources, decreasing the benefits from our national capital as a whole—that is, lowering its productivity in a broad sense.

It has often been observed that guiding rates of return are generally lower among the forest owners with the higher income. Such owners are under less immediate pressure to consume their income. They can put by a good deal of it, for they are able to attach more weight to future values. It may be supposed that as our economy grows and the disadvantaged sections come abreast of the others, this alone will serve to intensify timber management. To be sure, it will unless our rising income is attended by a diminishing propensity to save. We live in a time of extraordinary commercialism. Every successful advertisement, whether for tinned orange juice or chromed transportation, gives rise to demands for immediate consumption that compete with long-run conservation and make it more difficult for the nation to work toward intensive forestry.

Now to return to the question of wood demand in the long run—is there a simple answer? There is, I think, an inescapable answer. The greatest amount of domestic wood that the nation will want to see consumed is the amount that we can produce and still keep our national capital as productive as possible. Depending on the trend of our propensity to save and on our success at risk-reduction in forestry, and assuming no great changes in wood-growing technology, the amount in question, in terms of my rough estimates, is between twenty and perhaps twenty-four billion cubic feet per year.

THE SHORT VIEW

So much for the long run, which is, after all, a great way off and in most respects less exciting than the near future. What thoughts about the near future may be drawn from the long-run analysis?

Consider the problem of reaching the potential timber output from the starting point of today's forests and forest practices. The potential is higher than today's growth, so that to reach the potential will require building up growing stocks of young timber. The potential is also higher than today's cut, so that to reach the potential will call for increasing the drain on growing stocks. Here is a

dilemma in the making: a goal that necessitates both raising and lowering stocks. The fact is that not only do our demands for tin and chrome compete with timber conservation, but so do our demands for timber itself.

The brunt of the dilemma is likely to be borne by the exploitive class of small private forest holdings, the class widely viewed with alarm and called the crux of the forest problem in the United States.

Many of us know of some forest locality where an industrial concern is busy repairing its own forest lands: cutting its growing stocks only lightly so as to let them build up. Meanwhile the concern is buying most of its wood raw material from nearby farmers and so making a heavy drain on the farm woods. In this locality, then, farm woodland exploitation is the means for industrial forest conservation. What a predicament if the farmers insisted on being more conservative! Just so, we should face a national predicament if all forest owners should become ardent conservationists at once, or if society should try to set very high goals for the future or should try to reach goals quickly.

Hence the small, exploitively managed private forest holding is in a sense not a national problem in forest conservation, but a national instrument for forest conservation. All hail the little owner and his bad practices!

However, the quality of material that the little owner can contribute to the national wood basket is, on the whole, poor by today's standards. For a higher-quality means of sustaining wood output while we work toward larger goals for the future, there are the supplies of old-growth Western timber. To speed up the liquidation of these supplies would yield a three-fold advantage: It would take some of the pressure off the little holdings. It would arrest the decline in quality of current wood output. It would hasten the achievement of a young-growth forest economy with a relatively high growth capacity.

The relation between current and future wood output has its counterpart on the consumer's side of the forest. Since consumer preference is controlled in part by present and past consumption, high future consumption may require high consumption now. Here is perhaps the strongest social incentive for setting future wood-consumption goals low enough so that no excessive build-up of growing stocks and thus curtailment of consumption will be needed in the interim. Otherwise consumer preferences may be lost beyond ready regaining.

I contended earlier that consumers are free to put their own price tag on wood without greatly affecting the amount of it supplied. But surely there are limits to consumers' freedom. Very high prices on standing timber will drive consumers away from the end products unless unaccustomed progress is made in the technology of wood conversion, sufficient to offset the costliness of the raw material. On the other hand, very low prices on end products will foster wasteful utilization of raw material and even extinguish its value and put it out of reach—unless, again, improvements in conversion technology are enough to offset the cheapness of the products.

Technology in much of the forest economy has lagged behind that in other industries. If this trend goes on, we have the prospect of reaching, simultaneously,

values critically high for end products and critically low for raw material. Technological backwardness could result in giving the forest preservers and other non-timber interests more than they bargain for: the bulk of our forest lands all to themselves. We are used to thinking of timber as scarce. But economic forces now gathering momentum could change all this: Timber could become superabundant relative to the wood-products use that society could afford.

The preceding thoughts suggest some aims for near-future forest policy: Work for the gradual lowering of guiding rates of return in forestry by means of risk reduction and other measures consistent with keeping our whole capital fully productive. Do what is possible to hold wood values down toward the lowest levels consistent with reasonably close timber utilization. Recognize the true character of the so-called small-owner "problem," and refrain from wasteful crash programs to reform small owners. Encourage faster liquidation of remaining old-growth forests not required for non-timber purposes. Promote technological progress in the wood-using industries. Encourage wood imports and non-wood substitutes to meet demands in excess of an orderly and feasible schedule of domestic wood output.

Future Demands for Water

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If this discussion were to be confined to my own topic of future demands, the subject would be relatively easy to cover, but might not be very interesting to this discriminating audience, because it would be composed largely of statistics—statistics on the number of gallons of water used today by various kinds of industry, agriculture, and domestic purposes; and the anticipated increases in these uses by the “exploding population” we hear so much about. If my topic is combined with the idea of challenges in the use of natural resources, however, it becomes much broader in scope. It should deal with the general magnitude of water demands today, comparing them with available supplies on a national basis, and also contrasting demand-supply relationships in different regions of the country. Then, of course, it should make some realistic assessment of the future demand-supply relationships in different regions of the country, and suggest how serious the resulting water management problems may be. Finally, it should suggest a few possible solutions.

THE SITUATION

In this section of our discussion there are unlimited opportunities for using statistics on water supplies and demands—preferably expressed in gallons, so that the number of zeros following the few significant figures can be even larger than the Federal Budget. Such figures are certainly incomprehensible to the listener, and sometimes even to the author; so that the few water statistics I shall use will be expressed simply in inches depth. Thus, if you were standing in an open, level field, the thirty inches of average precipitation over the United States would hit the average person below the hips, and the thirty-eight inches average for New York State would hit him at just about the waist.

Thinking in terms of the whole country, of course these annual total figures on precipitation vary tremendously. In the Mojave Desert of Southern California, the average total is only an inch or two. At the other extreme, ninety or more inches of annual precipitation are recorded in the higher valleys of the Southern Appalachian Mountains and in the far Northwestern United States, particularly on the Olympic Peninsula of Washington.

As we think toward water demand, of course precipitation figures are descriptive, but not very quantitative. The reason is obviously that a large part of the precipitation is lost by evaporation. In New York State, almost half of our total precipitation is consumed by forests and other vegetation, and by direct evaporation from the soil and from water surfaces. At the other extreme, in the South-

western desert countries potential evaporation may reach seventy-five to eighty inches—the loss of water, that is, from such limited areas as stream beds, where water is always available for evaporation. Therefore available water supplies may range from essentially zero to not much more than half of the total precipitation anywhere in the United States.

Complicating this picture is the fact that streams don't run uniformly, and precipitation doesn't occur uniformly through the year. Characteristically, there is a high flow in streams during the spring of each year, as the result of melting snows or winter rains, and during the period before vegetation has developed into its fullest leafage. In contrast, the scattered showers and high rates of evaporation and transpiration in late summer mean comparatively low streamflow in most sections of the country. Thus we can say that our available average supply of water is poorly distributed, both geographically over the nation and even within any given area, and over the various months of the year.

As this paper was organized, I had before me a volume of statistics on water consumption. They are tremendous, especially for such a densely populated, highly developed area as New York State. As a matter of fact, the astronomic total of all the gallons that are used for industry, public water supply, the generation of water power, irrigation, and other purposes far exceeds the total annual precipitation—to say nothing of the total annual runoff. The reason is simply that these figures tell only how much water is diverted from the stream for these various uses or pumped from groundwater supplies—but they don't tell how much is returned to the streams after it is used. Actually, about 90 per cent of all the water that is used goes back into streams and is either re-used or flows into the ocean; on the average, only about 10 per cent is lost by evaporation and transpiration directly as a result of human uses. In the West, of course, the so-called "consumptive" use by evaporation and transpiration is far higher. In Colorado, for example, the consumptive use of irrigated crops is around twelve inches; in the hotter portions of the Southwest it may be as high as thirty inches. Such figures represent an actual complete loss to further human use.

From these comments you can see that the whole water supply-demand situation is so complicated that it is not easy to present in any simple form. About all that can be done is to state one generality: that even at the present time, the relation of demand to supply is becoming so critical that, even in the more humid regions such as New York State, real water shortages are felt every year in some areas, and in many places during very dry years. The use of water for supplemental irrigation, especially for vegetable crops, has been increasing by leaps and bounds wherever surface water supplies are available in vegetable growing areas. This is especially true in New York's Lake Plains counties where precipitation is less than other parts of the State, and where growers have discovered that in every growing season there are one or more periods during which precipitation is inadequate to produce an assured crop of high quality. Many canners and processors now refuse to contract in advance for crops to be produced on lands which cannot receive supplemental irrigation.

There are already a number of dramatic examples of the lowering of ground-water tables in areas where pumping of groundwater exceeds the available supply. An illustration is Long Island, where the Water Resources Commission has to exert stringent regulation on any new wells, so as to avoid further depletion of groundwater supplies and the encroachment of salt water from the ocean into wells on the island. A similar situation occurs on other coastal areas, especially southern California, where fresh-ground-water tables have been pulled down so far by pumping that there is a real downward gradient from the ocean to the groundwater table. There, of course, the ocean slowly moves in toward the wells, and the wells become unusable. In southern Arizona around the Phoenix area, even the combination of surface water and groundwater supplies is not enough to meet present demands. Every year the ground-water table goes down, on the average, so that now water is being pumped from depths as great as 150 to 200 feet or more below the valley surface. Greater pumping depths mean greater pumping costs. Therefore, little by little the cheaper crops such as hay go out of existence; the acreage of irrigated land becomes smaller; agriculture becomes confined to high-priced crops like cotton; and perhaps almost all agriculture will disappear from the valley. Then water will be available only for industrial and domestic uses, which can afford a high price. The final step would be stabilization of the regional population, so that supplies would equal demand.

WHAT LIES AHEAD?

This leads to the question of future demands. Again we have a supply of fascinating statistics to work from, dealing with the well-worn cliché "exploding population." In making projections toward 1980 or 2000, forecasters seem to be going on the assumption that population will continue to rise exponentially, like the increase of capital at a high compound interest rate. This means greater increases, year after year, until the mathematical end is an increase which becomes practically infinite each year. When we use this "end-point" method of logic, of course such projections show themselves to be absurd. The typical population growth curve is more likely to be S-shaped. For human populations, in fact, the growth curve has been a series of connected S's, with repeated periods that are essentially horizontal. Such a period we experienced during the great Depression of the 1930's, when the Natural Resources Commission predicted that the United States population would become completely stabilized: that births would equal deaths by 1960; and that we should need less schools than in 1936.

At present we are in a period of prosperity, with young post-war families and high birth rates; so the population is increasing rapidly. But all we need now would be a real stabilization of our economy, with slowly rising living costs, plus the further growth of "planned parenthood." Then we should very rapidly fall back to a stabilized population for a while. When we consider limitations on water and other resources, too, it is not at all impossible that this plateau might be projected much longer than in the past, and that any future growth rates would be far slower.

One more parallel could be drawn between the growth of human populations and those of plant and animal communities. Those other segments of the living populations of the world, also increase in the typical sigmoid curve. But when they get large, often they are brought rapidly down again by some catastrophe such as a forest fire or an epidemic. Through science we humans have reduced the risk of epidemics greatly, although it does seem that some of the organisms that attack human populations are beginning to resist even the most modern of our drugs. But science has also created weapons by which we can set up our own catastrophe. It is not at all inconceivable that within the next generation or two a completely new cycle of population growth may have to become established. Because of the genetic effects of radiation it may even be composed of beings that are not identical with our present human races.

Setting aside all of these relative uncertainties, however, it seems most probable that for the next twenty to fifty years the demand for natural resources including water will continue to increase, although I do not think we should venture to predict the rate. These increases will be conditioned in part by a further growth of population, and in part also by further demands for water by industry and other human uses.

HOW CAN FUTURE DEMANDS BE MET?

It has already been indicated that even under present conditions, available water supplies barely equal present demands, or even fall considerably short of them. I imagine we all agree, also that demands are likely to increase over the coming generation or two, although I hope you do not find yourself committed to the "explosion" concept. In any event, we have to consider how it will be possible to meet future demands for water resources. The various means for accomplishing this objective can be summarized in four categories.

First of these, because it is at present the most widely used, is the storage of water so that it may be held for future use or moved to some other point. This means, of course, the building of reservoirs, canals, tunnels, and other facilities for holding and moving water. Dams and reservoirs are created for flood control, which simply means holding back water when we have too much in our streams and letting it go when we have much less; for water power development; for public water supply; for irrigation of agricultural crops; for recreation; or for the improvement of navigation. More and more, reservoir developments are planned for a combination of these uses. This invariably means reservoirs of large size, simply because these different uses of water are not entirely compatible. For flood control alone, for example, it is necessary to keep the reservoir empty at all times, so that it may be filled by an excessively high streamflow during a flood, and can be emptied as soon as possible thereafter. For water-power generation, it is important to have water maintained at some level high enough so that its release will supply gravitational force to produce electrical energy in an efficient manner. And for domestic use and irrigation, the object is to keep the water supply in the reservoir as high as possible so that an ample supply is available

for times of drought. Closely correlated with the water-power and water supply problems are those of recreation, which also demand a considerable pool of water, but with the water level varying as little as possible. A conspicuous example of a major reservoir that is used for multiple purposes is Lake Mead on the Colorado River. Here the large flows of late winter and spring are accumulated, and released in a regulated manner to provide water for irrigation in the desert valleys below the reservoir, for power generation, for water supplied to the metropolitan water district of Los Angeles and other areas, and for widespread recreation in the form of boating and fishing.

The second category of methods for meeting future demands is water conservation. This means more efficient use, so that the smallest possible quantities are lost by direct evaporation into the atmosphere and are not again available for human use. Efficient use also means repeated re-use of the same water, either in the same industrial plant or after it has been discharged into a river and is picked up downstream. This, of course, is an extremely common form of re-use: one city and industry after another picks up water below the ones above it, and uses this water for its own purposes. Because the people upstream invariably leave the water in poorer shape than they found it, the result is that the downstream cities have to treat it in one or more of various ways, to remove bacteria, other forms of pollutants, chemicals, and sediment. In rivers like the Hudson, pollution is so serious that the City of New York at the downstream end has found it necessary to reach over into the headwaters of the Delaware River and into other hilly areas to get its supply of drinkable water. This is a disgraceful national situation: is there any other genus of animal on the face of the earth, that purposely befouls the water supplies that are available to its neighbors downstream? The solution, of course, is the abatement of pollution. This is becoming a major program on a national basis, with increasing assistance from the States and the Federal Government to make our rivers and other water bodies more nearly fit to use.

A third means of meeting future demands is the highly popularized conversion of salt-water to fresh. The mechanics of these processes are being perfected to a point at which such conversion will be practical for industrial and domestic use at points close to the supply of salt water. It seems inconceivable, however, that such converted water would be economically usable at any appreciable distance from the source. Consider, for example, that water from Hoover Dam costs the City of Los Angeles nothing at the point it is taken out of the river. The cost to the consumer is simply that of amortizing and maintaining the capital investment in canals, tunnels, and other appurtenances to move the water from the Colorado River to Los Angeles. Even this cost is still substantially below that of converting water in a plant right at the source. Thus it is logical that converted salt water would become usable for industrial and domestic purposes in and near the City of Los Angeles; but it seems hardly conceivable that it could be moved very far east in the southern California valley, and particularly not to such distant points as southern Arizona, which are in the most serious need of water.

The last of our four mechanisms for meeting future demands for water is one with which I am most familiar: watershed management. This could really be included under the term "conservation," because it means more efficient use of available supplies of water. Consider the gap between precipitation and runoff: a very large part of that gap is caused by evaporation and transpiration from vegetation. Then you immediately have to wonder whether it is not possible to reduce the amounts of water consumed by the plant populations of the world, so as to make more available for streamflow and ground-water. The mechanism for such reduction must, of course, be alteration of the existing vegetation on any areas: alteration by reducing the density of the vegetation, or by converting the existing communities of vegetation to some other form which would use less water. At the same time, any such efforts would have to be in harmony with the needs for soil stabilization and flood protection.

Therefore the problems of watershed management are very complex. They have been the subject of intensified research over the last quarter of a century, primarily in North America, but also in Europe and Asia. As a result, a series of principles have been developed and published repeatedly, which indicate various means by which vegetation may be manipulated in order to achieve increased water yields from any watershed area or river basin. Knowledge has also been gained as to the means by which these techniques can be regulated so as to prevent the occurrence of damaging erosion or floods. An outstanding illustration of the application of this knowledge is given by the Salt River Watershed in Arizona, which supplies essentially all of the surface and groundwater in the Salt River Valley surrounding Phoenix. Here private and public agencies, including the Federal agencies that administer the watershed land, are working together on a unique pilot project, designed to manipulate watershed vegetation for the purpose of increasing yields, while still maintaining soil stability and providing maximum opportunities for recreation as well as for the production of wood and forage products. I hope that similar projects can be undertaken in other parts of the United States, so that this mechanism can be more efficiently used to help meet future demands for water.

FURTHER STUDIES AND LONG-RANGE COMPREHENSIVE PLANNING REQUIRED

Even combining all of these mechanisms, there will come a time in the foreseeable future when the balance of water demands with available supplies even under the most intensive development will provide at least one mechanism for stabilizing the population of the United States. Water supplies are not unlimited; it is imperative that we do the very best we can, in the most objective ways possible, to use them wisely and well. This will require not only a further build-up of knowledge on the various mechanisms for better use; it will also require intelligent and mature cooperation among the people, replacing the many political expediences that seem to have dominated water-resource development during the past generations.

Municipalities will no longer be able to go it alone. Neither will industry, agriculture or outdoor recreation which is dependent on water resources.

Although the need for long-range planning on the most comprehensive basis has been declaimed by hydrologists and land-use economists so often that it has become a familiar refrain in professional circles, it is a need which has yet to be translated into effective public action, except in rare instances throughout the nation.

We must think and plan in terms of major watersheds. And we must create whatever intra-state, interstate, or interstate-federal machinery is required to carry out effective planning and action programs.

These are formidable tasks. For example, New York, New Jersey, Pennsylvania, and Delaware have struggled for over twenty-five years to establish interstate compact machinery for the Delaware River Basin. And yet, it is only in the last two years that we have finally been able to draft a new kind of interstate-federal compact which appears to provide a practical administrative mechanism. Even now, although this compact has been ratified by New York, and is in the legislative mills of New Jersey, Pennsylvania and Delaware under the best auspices, and has been publicly lauded by the Secretary of the Interior for the Federal Government, it is just possible that provincial or federal bureaucratic obstacles may cause further delay.

But as formidable as these tasks may be, I believe that man's necessity to solve our water problems, plus ingenuity, new knowledge and good will, make real progress certain. We can only hope, and work to the end that it is made as fast as our limitations permit. Our success will have much to do with the shape of the America of tomorrow.

Future Demand for Wildlife and Fishing

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Future demands for wildlife¹ and fishing, and future supplies of these resources depend upon at least the following factors:

1. The human population—its numbers, distribution, available free time, and amount of disposable income.
2. The demands of this population—for food, fiber, shelter, transportation, and other physical needs.
3. The pattern of land use required to meet these demands and the desires and standards of the future human population in terms of outdoor recreation.
4. The reaction of wild animal populations to the future pattern of land use, especially the increased intensity of use required to provide the maximum yield from each acre, and the lessened acceptability of non-conforming uses in multiple use.

Other than as necessary background, I shall not dwell on the human population, its physical needs, and the demands upon our resources to fulfill these needs. I have found the volume *Land for the Future* by Clawson, Held and Stoddard (1960) to be particularly useful, and I shall rely on it for facts and projections. The perspective given in this book seems to me more balanced than most, probably because the authors are not concerned with a single resource; and their treatment, though more optimistic than some others, does not depend upon a blind faith in the ability of technology to supply all of our needs.

THE HUMAN POPULATION

The estimated United States population for 1980 and 2000, and the actual 1956 population are shown in Table 1. The distribution of people between urban and rural areas, their expected work week, and their estimated total expenditure for recreation are also indicated in this table. The proportion of expenditures on outdoor recreation is not known even for the present, but Clawson *et al.* (1960: 135) state "... expenditures on outdoor recreation in 1980 may be in the rough order of three times those of 1956, and by the year 2000 they may reach six times the expenditures for 1956." The proportion of these expenditures dependent upon wildlife and fishing is probably substantial, and it is not likely to decrease markedly.

The breakdown of visits to intermediate and resource-based recreation areas is given because these two types of areas support fishing and hunting, and pre-

¹ Wildlife is used here to include primarily birds and mammals.

sumably bird watching and other non-consumptive uses of wildlife. Resource-based areas are those with superior natural features, and they may be distant from users; National parks and forests and some State parks and private areas are included. Intermediate areas are reasonably close to the users, and contain the best resources available within distance limitations; State parks and private areas are the principal examples (Clawson *et al.*, 1960).

In short then, we are concerned about the demand in 1980 of 240 million people with nearly one-fourth more leisure and nearly \$40 billion to spend on recreation; by the year 2000 there may be 310 million people with one-third more leisure, and \$88.5 billion available for recreation.

PATTERNS OF LAND USE IN THE UNITED STATES— PRESENT AND FUTURE

The increased human population will certainly exert different pressures and demands upon the land to fulfill its physical and spiritual needs. The uses of land in the United States for 1900, 1950, and projections for their use in 1980 and 2000 are listed in Table 2.

The projections are largely based on the premise that the demand for virtually every product and service the land can provide is sharply upward. With a fixed total area it is obvious that much of the demand will require more intensive land use, and that some of the demand cannot be satisfied.

Perhaps the most notable feature of these figures is that there is relatively little change in use up to the year 2000 as compared to the changes at the end of the last century and the beginning of this one. Phrased another way, the *kinds* and *quantities* of land use are becoming more stable and are likely to continue so; conversely, *intensity* of use within the major types of land use is likely to change markedly.

Table 1. Factors Related to Outdoor Recreation Demands
(From Clawson *et al.*, 1960)

ITEM	1956	1980	2000
Population			
Total	170,000,000	240,000,000	310,000,000
Urban	96,500,000	185,000,000	255,000,000
Rural	73,500,000	55,000,000	55,000,000
Work Week—Hours	40	32	28
Expenditures on Recreation.....	\$14,000,000,000	\$39,900,000,000	\$88,500,000,000
Recreation visits			
Intermediate ¹	312,000,000	1,200,000,000	5,000,000,000
Resource-based ¹	116,000,000	750,000,000	5,000,000,000

¹ Intermediate areas are not too remote from users, and are on the best resources available within distance limitations; resource-based areas are those with superior natural features and they may be distant from users.

Table 2. Use of Land in the United States in 1900, 1950, and
Projections for 1980 and 2000¹

(From Clawson *et al.*, 1960: 442)

USE OF LAND (MILLION ACRES) FOR	1900	1950	1980	2000
Cities of 2,500 or more population ²	6	17	30	41
Public recreation areas ³	5	46	72	95
Agriculture:				
Crops ⁴	319	409	388	388
Pasture ⁵	77	69	70	70
Other ⁶	53	45	45	45
Subtotal	449	523	503	503
Commercial forestry:				
Continuous management ⁷	0	359	385	405
Little or no management.....	525	125	90	50
Subtotal	525	484	475	455
Grazing ⁸	808	700	700	680
Transportation	17	25	28	30
Reservoirs and water management ⁹	*	10	15	20
Primarily for wildlife	*	14	18	20
Mineral production				
Deserts, swamps, mountain tops, some non-commercial forest, etc.	94	85	63	60
Miscellaneous and unaccounted for.....				
Total	1,904	1,904	1,904	1,904

* Negligible.

¹ The data in this table are necessarily estimates in several instances, sometimes on a relatively scanty basis of fact. This table emphasizes land use, as separate from land ownership or control or from vegetative cover.

² Includes municipal parks.

³ Excludes municipal parks, includes national park system, areas within national forests reserved for recreation, state parks and acreages around TVA and Corps reservoirs reserved for recreation. Excludes all areas used primarily for other purposes even though they provide much recreation. Excludes actual water area of reservoirs, which is shown later under its own heading. Excludes also wildlife areas, which are shown below. We have assumed that only part of the increased potential demand will be met. Data for past taken from *Statistics on Outdoor Recreation* (Washington: Resources for the Future, Inc., 1958).

⁴ Cropland harvested, crop failure, cultivated summer fallow, and cropland idle or in cover crops. See Tables 11 and 12, *Agriculture Information Bulletin* No. 168. U. S. Department of Agriculture, 1957.

⁵ Only pasture on land which is considered cropland is included. This corresponds to the 1949 and 1954 Census of Agriculture definition. The 1900 figure is an estimate.

⁶ Farmsteads, farm roads, feed lots, lanes, ditches, and wasteland. See Tables 11 and 12, *Agriculture Information Bulletin* No. 168.

⁷ This is a roughly estimated figure. For 1950, it excludes commercial forest land with no fire protection or poorly stocked, as shown in *Timber Resources for America's Future*, U. S. Forest Service, 1958. For earlier years, it is our estimate of comparable definition area.

⁸ Includes some noncommercial forest land used primarily for grazing.

⁹ Excluding land around reservoirs and conservation pools of reservoirs, which are included in recreation areas.

WILD ANIMAL POPULATIONS AND LAND USE

The use of land is, in the final analysis, the basic factor determining animal populations, for animal populations are products or byproducts of the land. The huge herds of bison that once roamed our prairies and the flights of passenger

pigeons that darkened our skies both are gone from the face of the earth, the victims of changed use of the land whose final disappearance may have been speeded but not caused by wasteful slaughter. The passenger pigeon is extinct, and the bison lives on in the United States only under fence. But changes in land use are not necessarily detrimental to all animal populations; some changes have provided additional habitat for certain species, and some of these, such as deer, have responded with current populations which far exceed the primitive populations (Taylor, 1956). Others, such as the chimney swift, have been able to take advantage of man's structures; still others, such as the red-winged blackbird, have adapted by substituting man's dependable agricultural crops for more variable wild foods. Populations of many species are less strikingly affected, but most wild animals are fairly specific in their requirements and their populations undoubtedly have responded, for better or worse. To generalize, the more diverse the environment, the more diverse the animal population that it will support; and unfortunately, the converse is equally true.

In the preceding section of this paper, it was noted that the trend in the future would be toward more intensive land use; toward making each acre used yield more of whatever product it is producing. Intensive use almost always brings about more homogeneous use, and consequently less diversity in small units of the environment. And intensive use also means that there is less opportunity for multiple use, less acceptance of competition with lower forms of life, in fact, less acceptance of losses from any cause. This trend is already clearly evident in agriculture, with the increased use of insecticides, fungicides, and "othercides"; the increased concern over bird and other animal depredations (which may also have increased in intensity as well as being less acceptable); and the trend toward larger fields for more efficient management. The trend is evident also, though perhaps less far advanced, on forest lands. Areas devoted to watersheds in arid and semi-arid regions are being managed for maximum water yields; control of wild fire is becoming better every year; increased efficiency in timber yield is being accomplished through single species stands controlled with chemical herbicides; increased control of insects and diseases through chemical insecticides and fungicides; and extensive investigations of means of alleviating animal damage through animal population reduction, systemic repellents, and other repellents. Even areas in the National forests devoted to recreation are being more intensively managed for recreation (U. S. Forest Service, 1961); our concern here must be that we do not dilute the very values we are striving to enhance.

Many land-use practices aimed at increasing the yield of the primary resource so alter environments as to make them less attractive and productive of wildlife. A few of them, particularly pesticidal applications, may cause outright mortality, which is most often inadvertent, but nonetheless real.

Perhaps one of the most striking examples of the impact of changing and intensifying timber management practices on a wild species is the case of the red-cockaded woodpecker. This bird, an inhabitant of the pinelands of the South, always nests in living trees infected with redheart, *Fomes pini*, (Steirly, 1957).

Saw-log forestry required old growth, but current forest practice results in cutting before trees become overmature and diseased. The result is that this woodpecker is almost bound to be exterminated unless some pine stands are deliberately managed to produce overmature trees with some disease, rather than all pulpwood.

With regard to multiple use of lands whose primary purpose is not for wildlife, Clawson *et al.* (1960: 449) consider that compatibility is high on lands used primarily for grazing and for forestry, fairly high on recreation lands, poor to high on reservoirs and water management areas, poor to moderate on agricultural lands, poor to fair on mineral lands, very poor on urban lands, and completely incompatible on lands used for transport.

Thus, the outlook for the future is generally for lower populations and fewer species of wildlife than exist today. The impact in regard to fish is less bleak, for multiple use of waters, including fishing, seems reasonably acceptable.

FUTURE DESIRE FOR FISHING AND WILDLIFE

It seems necessary to treat fishing and wildlife separately, for a variety of reasons. First, fishing is essentially the only recreational use to which fish can be put, whereas wildlife offers opportunities for photography and observing, as well as for hunting. Secondly, fishing is much more of a family recreation than is hunting, though not necessarily more so than other recreational uses of wildlife. Third, fishing is apparently more amenable to concentrated mass use than is wildlife, both because fishing gear can be used safely in closer proximity to other people than can guns, and because concentrations of people are less likely to disturb fish than they are birds and mammals. On the other side, one can well question whether the therapeutic values of recreational fishing can ever be realized under overcrowded conditions.

FISHING

Fishing as a recreational pursuit has increased enormously in the last few decades. In the year ending June 30, 1959, the most recent year for which figures are available, nearly twenty million people bought fishing licenses. Even this figure, which is one out of nine individuals in the total population residing in the United States, is low because many States require no license for fishing in marine waters. What of the future? In a recent report prepared by the U. S. Fish and Wildlife Service (U. S. Senate, 1960), the conclusion is reached that "Fishing opportunities are expected to increase in number in future years with the construction and improved management of artificial impoundments, reduction of stream pollution, increased interest in marine sport fishing, and utilization of presently under-utilized species. . . . Assuming that fishing license sales will increase at a rate somewhat more rapid than population to 1980 and in direct ratio thereafter, it is estimated that there will be 47 million fishermen in 1980 and 63 million fishermen in 2000. . . ."

There is some reason to consider the foregoing estimates of future numbers of fishermen high, in view of an apparent leveling off of the proportion of the

population that bought fishing licenses in the last few years (Figure 1), but such trends were discernible also in the 1920's and again in the late 1930's and early 1940's. Undoubtedly, data from a National Survey of Hunters and Fishermen now being assembled will give a better basis for judgment. My own personal inclination would be to assume that there will be an increase in numbers of fishermen, but that the very increase in numbers will tend to damp the rate of increase. It seems improbable to me that people will voluntarily subject themselves to the crowding that would be necessary to accommodate the numbers of fishermen estimated on the amount of water presumed to be available. Surely if they do, much of the value of fishing to the individual will be lost.

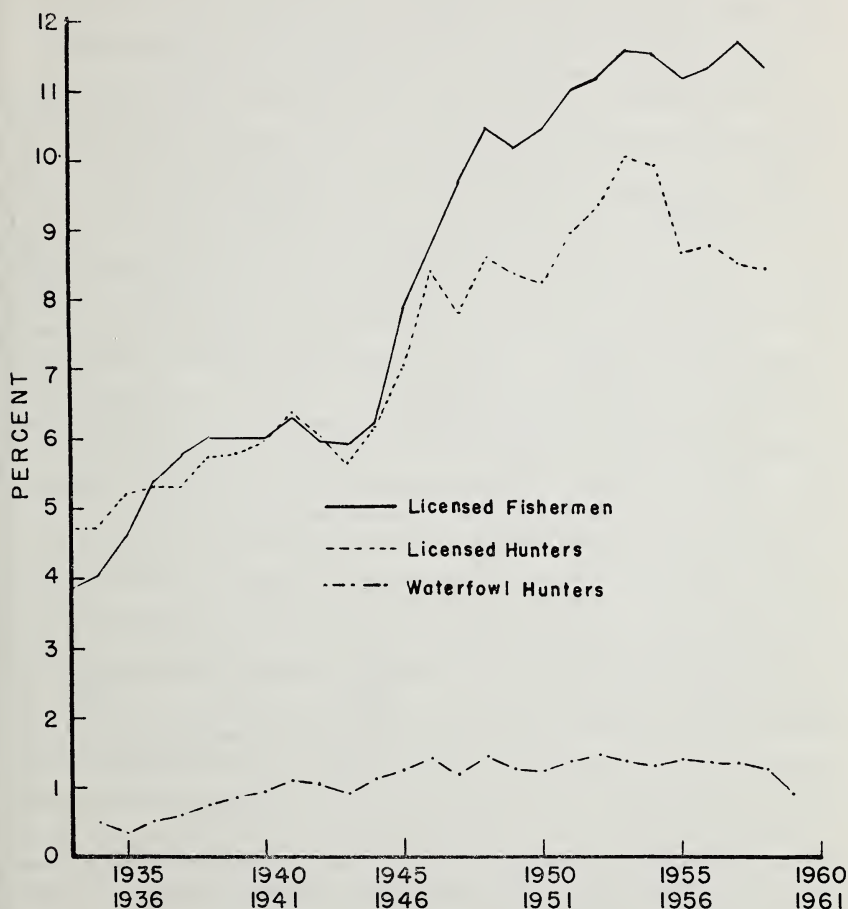


FIG. 1.—Percentage of license holders in the total population residing in the United States (license figures from information compiled in the Branch of Federal Aid, Bureau of Sport Fisheries and Wildlife; population figures from U.S. Census Current Population Reports, Series P-25).

WILDLIFE

Wildlife has played an important, varied role in the history of the United States. In Colonial times it was a source of food and clothing, a necessity that permitted existence and encouraged exploration. Later, during the era of the fur trade it was the prime cash crop. Now, however, its principal use to man is in providing recreation, offering esthetic stimulation, contributing to the health and naturalness of environments, and enhancing our social well-being through its recreational and esthetic values. (And as an administrator of wildlife research, I would be negligent if I did not acknowledge its scientific value as a vehicle for investigating fundamental natural phenomena.) While recognizing the existence of biological, social, and scientific values, as outlined by King (1947), I should like to devote the remainder of my paper to the recreational and esthetic values of wildlife, and what seem to me the changing ways in which these values are being realized.

We can divide the recreational use of wildlife into two types—consumptive and non-consumptive. Present programs of management seem largely aimed at satisfying the consumptive use, probably on the assumption that supplies of wildlife and conditions adequate for hunting will automatically provide sufficient wildlife and satisfactory conditions for non-consumptive users. Public policy, at least at the Federal level, recognizes both consumptive and non-consumptive uses of wildlife, for the Fish and Wildlife Act of 1956, as amended, begins with the statement that "The Congress hereby declares that the fish, shellfish, and wildlife resources of the Nation make a material contribution to our national economy and food supply, as well as a material contribution to the health, recreation, and well-being of our citizens; . . ." There is no distinction here between consumptive and non-consumptive recreational use. Hunting is indeed an important part of our recreational use of wildlife, and I, myself, am a confirmed hunter. Thus, the following paragraphs are not intended to deprecate the value of hunting; rather they are based on the premise that the importance of hunting is self evident. The virtues of hunting have been extolled by Clarke (1958), and the social impact of hunting has been debated by Anthony (1957) and Krutch (1957). It seems desirable to examine here who hunts and why.

The percentage of the population residing in the United States who bought hunting licenses and the percentage who bought Migratory Bird Hunting Stamps from 1934-35 to 1959-60, the most recent year for which data are available, are given in Figure 1. Both curves indicate a leveling off or even a decrease in the proportion of the population that hunts. The high point for all hunters was in 1953-54, when slightly over 10 per cent of the total population bought licenses. For duck hunters, the high was the preceding year, with 1.44 per cent of the population buying "duck stamps." We should not draw too hard and fast conclusions from these data, for they contain many variables; furthermore, at least in certain States, a similar trend was evident in the late 1920's. Another set of data bearing on this same point is shown in Figure 2 (U. S. Fish and Wildlife Service, 1960). It relates to visits to national wildlife refuges, where the number of visits for hunting increased only from 222,470 on 41 areas open to hunting

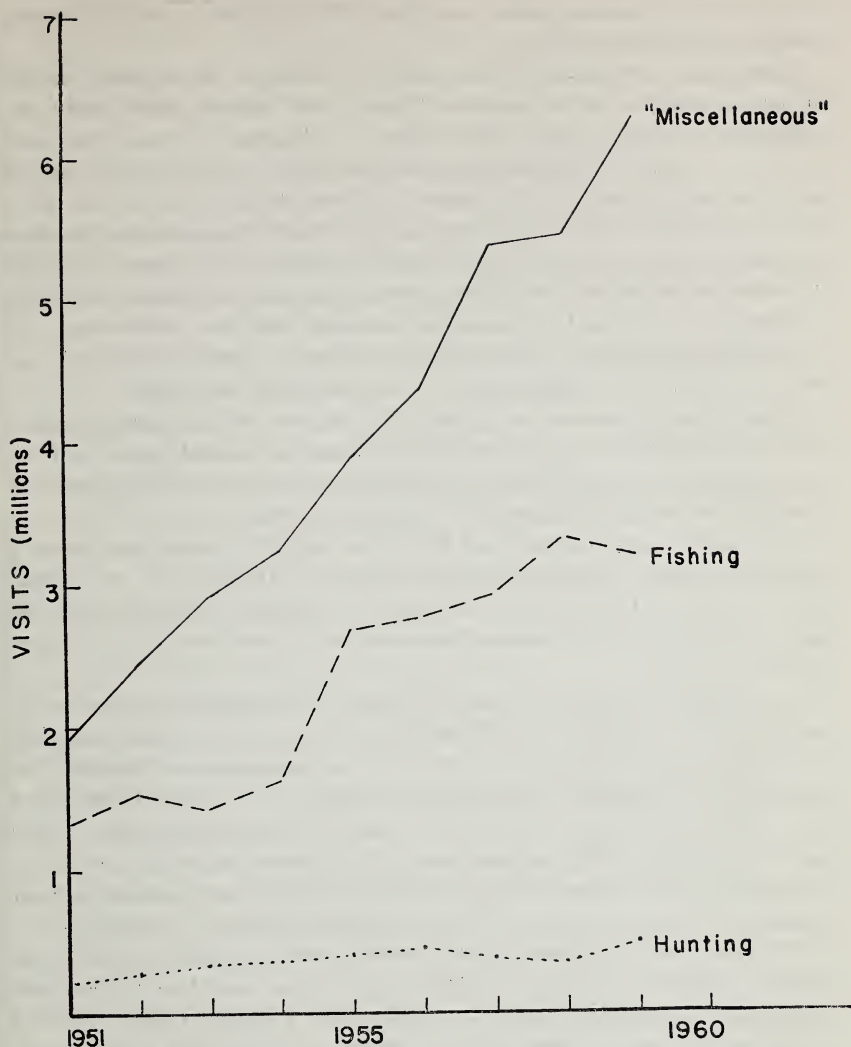


FIG. 2.—Visits to National Wildlife Refuges (from U.S. Fish and Wildlife Service, Wildlife Leaflet 420, May, 1960).

in 1951 to 481,504 on 76 areas open in 1959. It must be borne in mind, however, that the principal purpose of the national wildlife refuge is for use by wildlife, not people, and the areas open for hunting are rather small and vary from year to year, depending on the supply of game. During this same period of time, interest in bow hunting, a form of hunting obviously placing a higher premium on participation than on a trophy, has increased markedly. Figures from Michigan

show a thirty-fold increase in the proportion of the population buying bow hunting licenses from 1942 to 1957.

During this same period of time there are indications of increasing interest in non-consumptive uses of wildlife. Figure 2, for example, shows that "miscellaneous" visits to refuges exceed those for hunting by many fold, and, furthermore, that this difference is greater now than it was in the first years of record-keeping. In fact, in 1958 there were more than fifteen times as many "miscellaneous" visitors as there were hunters. While it is quite true that these people were not all attracted by the wildlife on the areas, it seems reasonable that substantial numbers of them were. Other supporting information shows that memberships in national organizations concerned with the out-of-doors, such as the Wilderness Society, National Audubon Society, Nature Conservancy, and the Sierra Club have increased three- to ten-fold in the last decade.

Other sets of figures that may perhaps be indicative of the degree of interest in the non-consumptive uses of wildlife are found in isolated places: In Utah, 20,000 people visited the Hardware Ranch, operated as an elk management area, to see and enjoy the elk during 1959 (Berryman, 1960).

There are at least fourteen local bird clubs with 1,735 members known to visit the wetlands of Hempstead and Oyster Bay, Long Island, and at least another 1,000 to 1,200 active birdwatchers not affiliated with any club. This compares with 5,000 duck hunters known to use the same area (U. S. Fish and Wildlife, unpubl.).

The burden of my thesis is, then, that there is an increasing amount of recreational use of wildlife, but that the trend in use is toward more observing, with a consequent decline in the *proportion* of participation in hunting. And it appears to me that this trend is likely to continue. A corollary to this trend, and a most serious one in many States, is that revenues from sportsmen's license fees are declining while costs are rising; and in most States, license moneys are practically the sole source of funds for fish and wildlife management. A recent editorial in *Michigan Conservation*, discussing this problem, concludes:

"The final answer, obviously, must be a new source of revenue. It seems inevitable that others who use and enjoy Michigan's resources will have to share with the hunter and fisherman the cost of conservation. The inescapable fact of this critical moment is that conservation in Michigan is in a kind of bread line, waiting for a handout to get through the day and hoping for a better tomorrow." (Anon., 1961).

Granting the existence of this trend toward more non-consumptive use, we may well ask why? To answer this properly requires some insight into why people hunt, and here we leave the realm of fact and shift to speculation. Peterle (1961) has attempted to shed some light on the question, but all we can ever find from the questionnaire approach is what the hunter chooses to tell us—and I suspect that even if he is scrupulously honest, he doesn't know why he hunts. Still and all, Peterle's respondents provide the best basis we have at present for judging: "Nearly half the hunters agreed they could be satisfied with a hunt if they didn't

kill any game; even a higher proportion (79 per cent) said that part of the pleasure of hunting results from seeing sunsets, bird nests, trees, flowers, and other wonders of nature. More than 70 per cent thought that we should set aside more wilderness areas." I submit that shifting away from hunting is a matter of quality. Quality in the sense of attractive, uncluttered wild places; in the sense of dependence on one's self; in the sense of freedom and solitude.

That eloquent philosopher of wildlife conservation, Aldo Leopold, long ago outlined what he considered the components of appreciation of wildlife (Leopold, 1948). He considered first the individual who must return with a trophy as a certificate of his ability, and these trophy seekers he divided into two kinds—those who reduce some wild thing to possession, and those who photograph or record. The first of these alters the environment, and thus, engaged in *en masse*, ultimately destroys the very things it values most highly; the second removes nothing tangible, and hence generally speaking, is much more subject to mass use without destruction. The second stage he describes is the feeling of isolation in nature, which also tends to be self-destroying. Third, he distinguishes "the fresh-air and change-of-scene component," which again tends not to be diluted by mass use. The last two components he lists are perception, or ecological comprehension; and finally, the sense of husbandry. He also pointed out clearly that "recreation is valuable in proportion to the intensity of its experience, and to the degree to which it *differs from* and *contrasts* with workaday life." The question then seems, what are we doing about it?

There are increasing evidences of public and professional awareness of this problem of quality in hunting. Even the *New York Times* has raised its eyebrows over the trend toward gadgeteering and the consequent decline in quality of outdoor recreation (*N. Y. Times*, Aug. 21, 1960. "What Would Daniel Boone Say?"). A recent meeting of the California Section of the Wildlife Society had as its theme "Quality vs. Quantity." In recent years, the "firing lines" that existed to slaughter migrating elk around Yellowstone Park, and on some of the goose management areas in the Mississippi valley aroused much public clamor and disapprobation. Today, serious consideration is being given as to how these surplus populations can be used to provide *quality* recreation. The U. S. National Park Service is wrestling with the problem of excessive big game populations on Parks and Monuments; undoubtedly animals must be removed to prevent range destruction. But can we remove them by hunting, and if we can, will it be recreation? Director Wirth has suggested the possibility of public assistance in removing these surpluses (Wirth, 1961).

In the Mississippi Flyway, several public shooting areas now control access by restricting travel to foot or manually propelled boats. These restrictions on travel operate through a stratifying process that puts the hunter most willing to work for it in the least crowded conditions. A report currently in preparation by the Planning Committee of the Mississippi Flyway Council outlines many additional steps that can be taken to enhance quality in waterfowl hunting. I have no doubt that other groups will do likewise for other areas and other kinds of

hunting as public dissatisfaction mounts, or as we in the wildlife profession awaken more to our responsibilities for providing quality as well as quantity.

CAN WE MEET THE DEMANDS?

It seems to me, as I have tried to point out above, that the demands are changing. Further, it seems to me that we in the wildlife profession should help these demands to change—that we should leave behind our preoccupation with more and more targets and shift some of our efforts to enhancing quality. Targets as such can best be supplied by private shooting preserves which concentrate on quantity, and will doubtless attract those who are willing to accept an artificial product. Kozicky (1961) has shown a doubling in number of shooting preserves to 1,700 now, and a quadrupling of targets to 1,500,000 during the past six years. Those of us concerned with public recreation will do well to concentrate on quality, and on maximum diversity in natural surroundings. We must concentrate on providing opportunities to enjoy wildlife and fish, on the occasional trophy, and the unusual observation, and not on meat in the pot. And we will certainly do well to promote perception and understanding. To the degree we offer esthetically pleasing contrast to day-to-day experience, so will we meet the future needs of our people.

CONCLUSION

The human population of the United States is increasing rapidly, and by the year 2000 may exceed 300 million people. The requirements of these people for food and fiber, living space, and water can be met, but the shifts in land use necessary to meet them will increase the problem of providing wildlife and fishing in sufficient quantity and quality. It seems probable that the demand for fishing may be met by the increased amount and lessened pollution of water available, the utilization of species not now fully utilized, and by shifting of more fishing pressure to marine waters. Demand for wildlife can be met, it seems to me, only by concentrating on offering quality rather than quantity—the opportunity to hunt rather than the guarantee of a carcass to be brought home; and by the shifting of a substantial portion of our use from consumptive to non-consumptive uses. Creating in the public a greater appreciation and ability to perceive is one of the most hopeful means of accomplishing this change to greater non-consumptive use.

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PART FOUR

CHALLENGES IN
FOREST PRODUCTION



Physiological Implications

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There is widespread agreement on the need for handling forests to produce selected species of trees with improved form, good quality, and fast growth, as well as resistance to insects and disease. These objectives are indeed challenging for forests are exceedingly complex and dynamic ecosystems. Many of them are composed of a variety of species of trees of different ages, different morphological characteristics, different rooting habits, and varying capacities to endure environmental stresses. Throughout their development the members of such complex plant communities undergo severe competition. As a result, growth of individual trees is inhibited. A real difficulty in producing specified forest products on a given area is that seriously disturbed forests tend to return to the original type. For example, in a twenty-year period hardwoods replaced pine as a forest type on thirteen million acres of land in the south (66). Nevertheless the increasing demands for specified forest products will necessitate favoring transitory species and maintaining many forests in what is really an artificial state. These considerations call for increased knowledge of the fundamental nature of tree growth, its biochemical machinery, and variations in physiological response of different species to environmental stress.

This paper will emphasize physiological implications in tree growth and point up some of the critical areas in which physiologists can make contributions to meet the challenges in forest production.

INTERNAL CONTROL OF GROWTH

To a physiologist the predominating feature of a tree is its ability to make itself. Throughout its life span a tree is supplied by its own leaves and roots with such essentials for growth as carbohydrates, hormones, minerals and water over increasingly longer translocation paths. This necessitates a delicate balance between organs and precise correlations in rates of physiological processes, including photosynthesis, respiration, nitrogen and fat metabolism, enzymatic activity, translocation and assimilation. The amount of growth which occurs over a given time depends to a considerable extent on important regulatory mechanisms of food conversion in addition to food synthesis.

As emphasized by Kramer (119) the contribution of physiologists in improving forest production lies in their responsibility for identifying and characterizing the fundamental processes in trees which influence growth and for demonstrating how these processes are affected by heredity and environment. Kramer pointed out that physiological processes must always be recognized as the critical intermediaries through which heredity and environment interact to influence growth.

Silvicultural treatments which alter growth do so only through their influence on carbohydrate production, assimilation, hormonal relations, water relations and other internal conditions. Furthermore, decreased growth or, ultimately, death, as a result of insect attack or fungus disease inevitably is preceded by critical disruption of physiological activity. In fact, all changes in tree growth occasioned by environmental changes, cultural changes, or changes in genotype are linked always to internal physicochemical processes and conditions.

The importance of internal controls is emphasized by time-lag responses of trees to environmental fluctuations. For example, the absorption of water lags behind transpiration and tree leaves and stems tend to dry out during the middle of the day (115). Hence, environmental conditions which are conducive to high transpiration eventually, but not immediately, cause leaf desiccation and in turn reduction in photosynthesis. The rate of flow of maple sap on a particular day is more closely related to temperature conditions of the previous day than to the day of flow measurement (145). Vegetative growth and reproduction are affected by environmental changes but only after a time lag during which internal changes occur. Using regression analysis Fritts (52) found that light intensity of the day of measurement exerted a direct effect on diameter growth of hardwoods for two days thereafter. He attributed this to a lag in translocation of photosynthate to the measured region of the stem.

The actual lag in certain growth responses to environmental changes may cover a considerable period of time. Holmsgaard and Olsen (77) demonstrated that seed production in beech was correlated with weather conditions of June and July of the previous year. Motley (155) found that low amounts of rainfall during May to November in 1940 and 1944 were followed by decreases in height growth in 1941 and 1945. When rainfall increased during the growing season of a particular year height growth was increased the following year.

It is well known that terminal shoot formation of many Temperate Zone trees is a two-stage process requiring two years. During the first year the bud containing primordia of the following year's growth is formed. Hence, Sacher (179) found that winter buds of pine trees contained unextended internodes with all the primordia of growth for the following season included. During the second year the parts already contained in the bud extended into a shoot.

A favorable environment during the year of bud formation is translated into a large amount of shoot growth the following year, unless unusually severe environmental stresses occur during the period of shoot elongation (125). However, height growth of most Temperate Zone species occurs during only a short part of the frost-free season and thereby escapes severe late-season environmental stresses such as droughts. Kienholz (90) found that in New England maples, red oak, white ash, beech and white, red, Scotch and jack pines required only thirty days to complete 90 per cent of their height growth. Gray and white birch and aspen had longer growing seasons; yet they completed 90 per cent of their height growth within approximately sixty days. Other studies emphasize that height growth of many species occupies only the relatively early part of the

Table 1. Variations in length of growing season. Height growth data for nursery-grown seedlings during the growing season of 1954 in Central Massachusetts. From Kozlowski and Ward (110, 111).

SPECIES	DATE GROWTH STARTED	DAYS TO COMPLETE 90% OF GROWTH
<i>Gymnosperms</i>		
<i>Picea abies</i>	April 15	57
<i>Picea glauca</i>	April 20	99
<i>Abies balsamea</i>	April 15	82
<i>Tsuga canadensis</i>	April 15	93
<i>Angiosperms</i>		
<i>Gymnocladus dioica</i>	April 19	36
<i>Sorbus americana</i>	April 19	39
<i>Acer saccharum</i>	May 1	75
<i>Betula papyrifera</i>	April 19	98
<i>Hamamelis virginiana</i>	April 24	84
<i>Cornus florida</i>	April 24	95
<i>Aesculus hippocastanum</i>	April 19	91

frost-free season (31, 116, 96, 110, 111, 112, 125) (Table 1). Since terminal shoot elongation of many species starts early in the season and much or all of it is completed by the time the leaves have produced only a fraction of their total seasonal photosynthetic output, height growth of many species probably depends to a considerable extent on stored carbohydrates rather than on currently produced photosynthate. McGregor (149) observed that in North Carolina significant amounts of carbohydrates were not produced by white and loblolly pines until June but by that time much of the year's height growth was already completed (Table 2). Clark (30) found that the new foliage of balsam fir released more carbon dioxide in respiration than it utilized in photosynthesis early in the growing season, thus reemphasizing the importance of translocated foods for shoot elongation (Figure 1). In England Rutter (177) showed that about half the height growth of Scots pine seedlings was completed by May 26 but total dry weight of the whole plants decreased up to that time. During the time of shoot elongation the old needles decreased in dry weight approximately as much as the new shoots increased in dry weight. These facts reemphasized that the new shoots grew at the expense of carbohydrates stored in the old needles. Such observations also stress that growth is internally controlled and depends on food reserves and other growth factors and conditions which often are related to an environmental regime of the past. It is not until critical biochemical adjustments are realized that growth responses occur.

Table 2. Seasonal changes in the rates of photosynthesis and respiration of loblolly pine and white pine. The loblolly pine seedlings were in their second season and the white pine seedlings in their fourth season. From McGregor (149).

Monthly excess of photosynthesis over respiration in gms. CO₂ per plant.

	LOBLOLLY PINE	WHITE PINE
January	—0.596	—0.356
February	—0.564	—0.514
March	0.525	0.366
April	1.679	1.757
May	8.837	8.011
June	14.282	12.170
July	24.920	15.419
August	32.249	17.179
September	34.604	20.224
October	31.527	11.614
November	19.755	5.147
December	7.443	0.976

Internal growth control also can be demonstrated by variations in the rate and duration of shoot elongation on different parts of the same tree. As may be seen in Table 3 annual shoot growth tended to decrease progressively downward and inward in the four highest whorls of branches in red and white pine trees. Annual growth of four stem axes was in the following order: primary > secondary > tertiary > quaternary. Also, within an axis growth decreased in each whorl from the top downward. The physiological mechanism of such correlative growth inhibition within a tree is not fully understood, but auxin and food relations appear to be variously involved (185, 198, 219, 220, 23, 25, 62).

Table 3. Variations in shoot elongation during 1960 on different locations of stems of six-year-old conifers grown at Wisconsin Rapids, Wisconsin. All measurements are in centimeters. From Kozlowski and Ward (112).

	PRIMARY AXIS	SECONDARY AXIS				TERTIARY AXIS					QUATER- NARY AXIS	
	(Ter- minal Leader)	Whorl Number				Whorl Number					Whorl Number	
		1 (Ter- minal)	2	3	4	2	3		4		3	4
							Up- per Set	Low- er Set	Up- per Set	Low- er Set		
Red Pine	57.7 ±6.2	34.6 ±7.7	32.5 ±4.9	27.7 ±5.4	15.4 ±8.0	17.1 ±5.8	15.3 ±5.4	13.7 ±4.5	11.5 ±4.9	8.1 ±4.8	6.2 ±2.7	4.7 ±2.5
White Pine	44.3 ±7.6	25.5 ±8.2	24.8 ±7.0	19.1 ±4.1	14.1 ±2.2	12.3 ±5.1	10.5 ±3.4	9.5 ±3.4	7.8 ±8.4	7.3 ±3.7	4.3 ±0.6	3.0 ±0.5

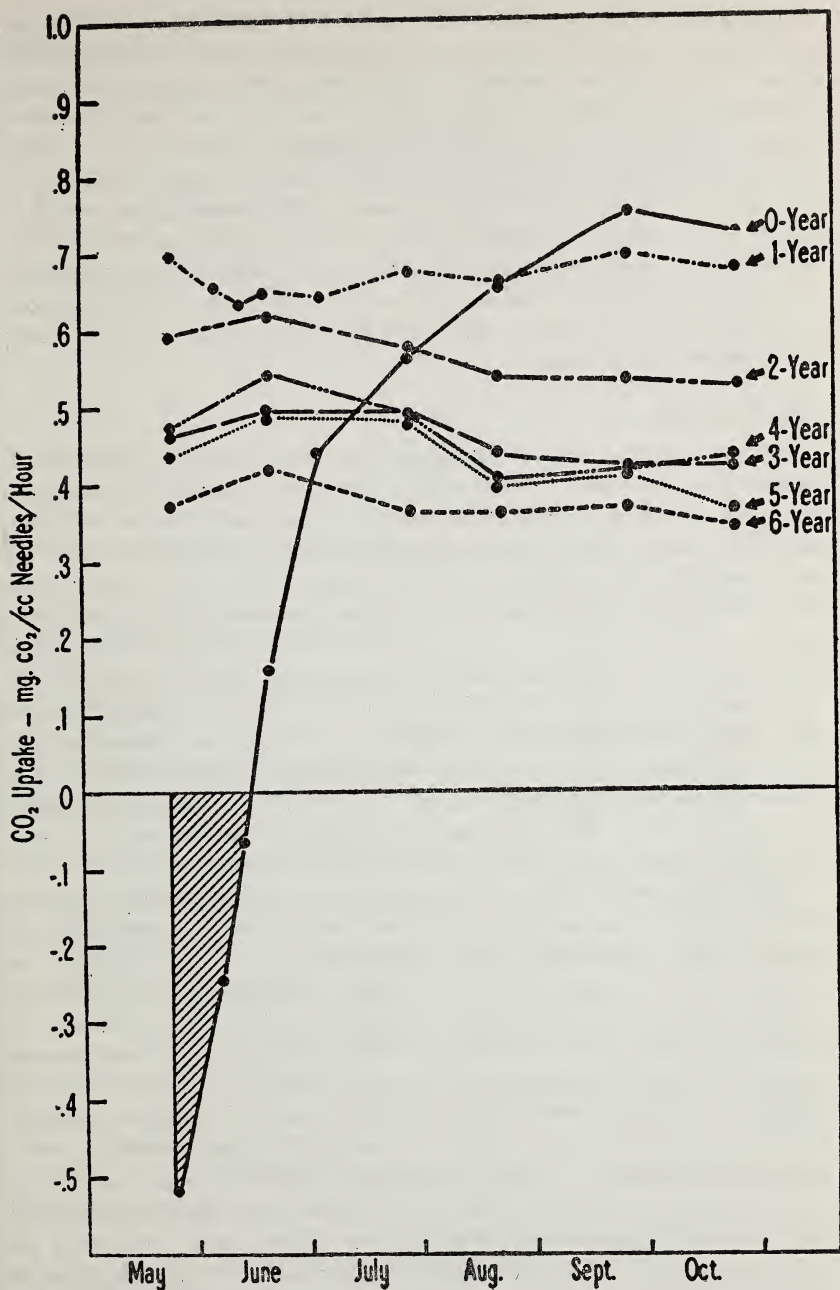


FIG. 1.—Seasonal photosynthesis of balsam fir needles of varying age. From Clark (30).

IMPORTANT PROBLEM AREAS IN PHYSIOLOGY

Since growth of trees is essentially an outward manifestation of rates and coordination of physiological processes it is important to know how the efficiency of each of these processes varies in different species under optimal environments and under varying degrees of environmental stress. In the past many silvicultural investigations too often stopped with an evaluation of end results only. Much more progress would have been made if there had been more concern as to why these results came about (119). Hence, future investigations should be focused on physiological responses of trees to climatic, edaphic, and biotic factors. More basic information is needed on how trees grow. Some of the more important physiological implications and research needs in the areas of food, hormone, water and mineral relations as well as seed physiology will be considered briefly in the following discussion.

FOOD RELATIONS

The raw materials and energy required for wood formation ultimately are derived from reduction of carbon dioxide. Therefore a thorough knowledge of variations in photosynthetic capacities of forest trees and of effects of factors controlling photosynthesis is basic to effective control of forest production. Man can manipulate photosynthesis to good advantage. To do so he needs to know that photosynthesis is influenced by a complex of environmental factors including light (70, 207, 124, 94, 97, 13, 14, 15, 17, 18, 19, 204, 205, 214), temperature (85, 37, 49, 164, 128), carbon dioxide concentration of the air (38, 200, 80, 125), soil moisture (180, 27, 4, 137, 94, 14, 157, 227), soil fertility (68, 26, 171, 138), leaf coatings such as fungicides, herbicides, and insecticides (83, 125), and disease (139, 41, 125). In addition photosynthesis is influenced by several tree factors such as age of leaves (50, 160, 172), structure and arrangement of leaves (165, 166, 123), stomatal distribution and behavior (161, 44), chlorophyll content (206, 125), and carbohydrate accumulation (136, 125).

Large differences in capacity for photosynthesis occur among species and even within species. These variations often are correlated with growth rates. For example, Huber and Polster (82) observed differences in photosynthesis of different clones of poplar species and hybrids. Photosynthesis was about ten times as great in a Wettstein hybrid as in *Populus nigra* and the difference in photosynthesis was correlated with the amount of wood produced. Bourdeau and Mergen (19) found that primary and secondary needles of diploid *Pinus elliottii* seedlings had higher rates of photosynthesis than had polyploid seedlings (Table 4). The lower photosynthesis in the polyploids was correlated with a depressed growth pattern. Higher photosynthetic capacity also has been demonstrated by Bjurman (11) for diploid *Ribes satigrum* plants than for tetraploids. Since the diploids had approximately 45 per cent more stomates per unit of leaf area and a slightly lower chlorophyll content than the tetraploids, Bjurman attributed the differences in photosynthesis to anatomical differences providing for more ready diffusion of carbon dioxide into leaf mesophyll in the diploids.

Table 4. Respiration and photosynthesis in diploid and polyploid shoots of *Pinus elliottii* Engelm. expressed on a fresh weight basis. From Bourdeau and Mergen. (19)

		RESPIRATION Micrograms CO ₂ /min/g		NET PHOTOSYNTHESIS AT 2000 F.C. Micrograms CO ₂ /min/g	
Seedling	Needle Type	2n	Xn	2n	Xn
1	Primary	40.2	41.1	37.6	7.3
2	Secondary	16.7	12.7	25.5	8.0

Milner *et al* (152) found considerable difference in the rate of photosynthesis of different races of trees of the same species. These examples emphasize that short-time photosynthetic measurements undoubtedly will be exceedingly useful for identifying phenotypically normal individuals within species, hybrids, or ecotypes with exceptionally rapid photosynthesis and potential for unusually high cellulose production. Richardson (173) pointed up the usefulness of such an approach for selecting parent trees for vegetative propagation or controlled breeding. Such an approach to tree improvement will involve problems of measurement of photosynthesis (164, 39, 79, 80, 81, 93, 125), leaf measurements (109, 151, 158), and interpretation of data (40).

For many years horticulturists have been well aware of the need for continuing studies on photosynthesis of trees as related to environment. From their basic studies they have learned much about how to grow trees. Yet, many of their problems are less complex than those involving forest trees. Orchard trees, which are widely spaced, do not undergo the intense competition prevalent in a stratified forest consisting of closely-grown trees of different species.

Many problems in forestry are traceable to practices which were physiologically unsound at the outset. Species have been planted in areas where they could not survive competition because of their inability to carry on photosynthesis effectively at low light intensities (124, 94, 125). In other areas forest trees are inefficient at high light intensities because their maximum photosynthesis is reached at a relatively low light intensity. Further increase of light intensity above a critical intensity results in rapid carbohydrate depletion because of increased respiration but no increase in photosynthesis (125). In Europe Tranquillini (205) reported that while sun plants of *Pinus cembra* fixed more carbon dioxide at higher light intensities than did shade plants, the concomitant increase in respiration decreased net photosynthesis. Tranquillini concluded that in one locality the total amount of sunlight available for photosynthesis was at least four times that needed for best growth of trees. Bourdeau and Laverick (18) explored the relationship between degree of tolerance and photosynthetic adaptability to light intensity in forest trees. They found that chlorophyll content might be limiting in white and red pine but not in hemlock. These experiments are cited as examples of

basic research and outlook which will be extremely revealing in getting at the fundamentals of growth control in forest trees.

The tendency for use of chemicals such as herbicides, insecticides, and fungicides in forestry raises questions about the specific effects of these materials on photosynthesis of forest trees. Many fungicidal and insecticidal sprays reduce photosynthesis in varying amounts, primarily by clogging stomates or by reducing the light available to mesophyll tissues. A considerable body of knowledge on the effects of leaf coatings on photosynthesis of orchard trees has accumulated (69, 75, 76, 83, 92, 167, 168, 215, 216, 72). However, data for forest trees are very sparse. Wedding *et al* (215) observed that photosynthesis of citrus was depressed rapidly by petroleum oil sprays in amounts commonly used as insecticides and that inhibition of photosynthesis persisted for as long as two months. Heinicke (69) also noted that lime sulfur sprays reduced photosynthesis in apple trees by about half during the first five days after spraying. This represented a dry matter loss equivalent to that of a half bushel of apples. According to Helson (72) the botanical insecticide ryania reduced photosynthesis in trees with each of four applications at ten-day intervals until photosynthesis was reduced by 40 per cent. Hyre (83) reported that every one of twenty-two fungicides he dealt with reduced photosynthesis in trees. If several chemicals are equally effective as insecticides or fungicides, there obviously is real value in selecting the one that will interfere least with photosynthesis and with the ultimate production of wood. But we cannot speculate about these things. We need good data based on research.

With more industrialization and greater concentrations of people there will be greatly increased possibility of growth inhibition of trees as a result of air pollution by discharges from factories, stoves, incinerators, and motor vehicles. There already is serious concern about smog damage. Experiments with ozonated hexene as a synthetic smog emphasized that smog reduced photosynthesis and growth (197, 201). Sulfur dioxide injury also has been well documented. Reduced photosynthesis undoubtedly is involved. In British Columbia tree growth was depressed by sulfur dioxide injury as far as forty miles from the emission source (87). Smoke and dust also depress photosynthesis. Many years ago Toumey (203) concluded that growth of conifers in Connecticut was reduced by 25 to 50 per cent by smoke. More recently Ersov (46) found in Russia that photosynthesis of *Tilia cordata* and *Ulmus pinnato-racemosa* was greatly decreased by a covering of smoke-grime. Dry weight increase of smoke-grimed leaves of *Tilia* was 43.3 per cent and of elm 23.1 per cent less than that of clean leaves. Ersov attributed these decreases to altered light and temperature conditions, but stomatal plugging probably also played a role in depressing photosynthesis. It will be increasingly important to identify species which are resistant to various air contaminants. The marked variations in response to environmental stresses of different species emphasize the need for building up a body of knowledge of factors controlling photosynthesis in different species and ecotypes. Information is especially needed on photosynthetic responses to light, water, air pollution, defoliation, and disease. The greater demands for wood and more intensive management of seed orchards

and plantations will tend to make many of the problems of horticulturists and foresters more alike. For these reasons there undoubtedly will be more environmental manipulation and more control over photosynthesis of forest trees than in the past.

It should not be inferred from the emphasis that has been placed on photosynthesis that growth is controlled solely by the amount of available food. Tree growth often is checked rather suddenly even when trees have substantial carbohydrate reserves. Working with precisely controlled environmental conditions, Kramer (121) demonstrated that even under conditions of adequate light, moisture and minerals, loblolly pine seedlings grew in surges. Furthermore, when certain species of trees are subjected to long photoperiods they show greatly increased growth even when the additional light is of very low intensity. This suggests that food synthesis and food conversion are not necessarily coordinated. Other internal controls such as auxin deficiency appear to play important roles in growth inhibition when carbohydrate supplies are sufficient. There is unmistakable need for thorough study of the relative efficiencies of different species in assimilating carbohydrates and of the biochemical changes occurring during food conversion. This was emphasized by Ryuzo and Davis (178) who found marked differences among varieties of trees in the ratio of photosynthesis to rate at which dry matter was accumulated.

HORMONE RELATIONS

Growth of trees is affected by internally produced growth substances in addition to foods, minerals, and water. Among the best known of these growth-regulating substances are the auxins which cause elongation of shoot cells. They play a paramount regulatory role in several aspects of growth such as shoot elongation (125), diameter growth (188, 190, 8), root growth (7), wound healing (183), formation of galls and tumors (132, 91), fruit development (140, 142), and prevention of abscission of leaves (135, 184, 1), and fruits (141).

The field of hormone physiology provides a good example of how basic physiological research and practical uses are related. For example, it was found that natural auxin from the tip of a cutting promoted rooting, and debudding of cuttings decreased root initiation. Rooting of cuttings also is enhanced by treatment with indolebutyric, naphthaleneacetic and indoleacetic acid and their potassium salts and esters (43, 199, 143). After treatment with such synthetic root-inducing substances carbohydrates are translocated to the base of the cutting, respiration increases and the number of root primordia increases (89). However, rooting of cuttings is influenced by a variety of factors including age of parent tree, season when cuttings are taken, and the part of the tree sampled (125). The inability to root cuttings from older trees has been a serious deterrent to forest tree improvement, and much more information is needed on the physiology of rooting.

Horticulturists have extended basic researches on hormones to produce parthenocarpic fruits with synthetic growth regulators (34, 162), to shorten the time

required for fruit ripening (144), and to increase fruit size (45). Control of preharvest drop of fruit in apple and pear orchards with hormone sprays has been developed as a standard practice which has decreased loss of fruits by preharvest drop by some 60 to 80 per cent (9). These practices have come about as a result of considerable basic research.

Over the years such characteristics as fast growth and good form have been primary objectives in handling of forests. More recently much interest has been shown in improvement of wood quality. It is well known, for example, that pulp yields are correlated with wood density. Hence, trees with wood of high specific gravity reflect high quality for lumber and pulp. In many gymnosperms there is high correlation between specific gravity and proportion of springwood to summerwood in the annual ring. Therefore, the physiological mechanism which controls the initiation of summerwood formation is of the greatest interest not only to academicians but to the most practical man interested in more pulp per cord of wood. Mitchell (153) found that in the same species a cord of wood of high density produced twice as much pulp as the same volume of wood of low density. Zobel and McElwee (229) found specific gravity in loblolly pine to vary from 0.40 to 0.68. There is evidence that by selection and breeding it will be possible to develop wood of high specific gravity.

Wareing (211) postulated that the springwood-summerwood transition was auxin controlled. Later Larson (130) demonstrated that under long photoperiods red pine seedlings produced springwood-like cells for an extended period, but when moved to short-day conditions summerwood-like cells were produced. Summerwood-like cells could also be induced by decapitation while application of exogenous auxin to decapitated seedlings induced limited production of springwood-like cells. Larson concluded that large-diameter cells were produced during the time of active elongation and high auxin production. Narrow-diameter summerwood cells were produced after terminal growth ceased and terminal auxin production declined.

Another important research area involving hormones is that of flower induction. The continuing emphasis on forest tree improvement intensifies the dire need for understanding the internal processes which control flowering. Basic information on the flowering mechanism would be invaluable in devising methods for stimulating early flowering and seed production in tree breeding programs. Although precocious flowering has been reported in forest trees (150) it is uncommon and most forest trees grow only vegetatively during a juvenile period. The length of the juvenile period during which flowering does not occur varies greatly among species. Whereas *Pinus sylvestris* does not flower for five to ten years *Fagus sylvatica* does not flower until thirty to forty years old (213). It is possible to accelerate seed production in older trees by crown release, fertilization, girdling, phloem inversion and root pruning (3, 217, 218, 63, 78, 10). Unfortunately, this cannot be readily done in juvenile trees. There is considerable evidence that hormones play an important role in creating favorable conditions for flowering. Harada and Nitsch (64) demonstrated that profound quantitative

and qualitative hormonal changes occurred during flower development. Wareing (212) showed that young Scots pine trees produced female cones in five to seven years but male cones were not produced until ten to fifteen years. In young trees female cones were produced only on strong leading shoots, either leaders of lateral branches or the terminal leader. Male cones were first produced on shoots of lower morphological categories on basal branch regions. As a branch aged male cones were produced higher on the branches. Eventually male cones were produced close to female cones on leading branch shoots. These observations suggested a causal relation between shoot vigor and bud type. Reduction in shoot vigor associated with aging was linked with a changeover from formation of female to male cones. Such observations indicate different internal requirements for female and male cones and suggest that food and hormone relations are involved. That chemical composition influences flower formation has been known since the early studies of carbohydrate-nitrogen relations. Davis (36) believes, however, that a change in carbohydrate-nitrogen ratios is a result rather than cause of flowering. Chailakhjan (24) believes that many organic substances are involved in the process of flowering but that flowering hormones are of greatest significance. According to DeZeeuw and Bosweg (42) the role of auxin in flowering changes with the vegetative status of the plant. They found that in the presence of young growing tissue the influence of auxin appeared to be inhibitory. DeZeeuw and Bosweg suggested, therefore, that floral initiation may not require specific factors but rather mobilization or redistribution of normal growth factors away from young, growing tissue. They advocated a more intensive emphasis on translocation with tracer techniques as a useful approach to the flowering problem. Stanley (191) emphasized that the role of auxins and anti-auxins on metabolic patterns leading to production of floral primordia may be through their influence on the kinetics of plant enzyme systems. Stanley's important work showed that differentiation does not appear to be related to intercellular differences in nucleic acids or micronutrients. Roberts and Struckmeyer (174) reported that floral induction was associated with lipid physiology. They isolated a crude lipid extract which in minute quantities induced flowering. Kessler *et al* (89) suggested a possible relation of flowering to an increased RNA/DNA ratio. These several independent findings reflect the importance of identifying specific flower-inducing substances. Yet much greater emphasis on such work is needed for, as Nienstaedt (159) points out, there is a truly urgent need for studies on the basic mechanism controlling flowering in addition to the considerable research now underway on effects of environment on the amount of seed produced.

An interesting case of the use of synthetic hormones to promote flowering involves the subtropical lychee tree. Normally with adequate moisture this tree flowers poorly because of its rapid vegetative growth during the period when floral primordia would otherwise develop. However, applications of sodium naphthaleneacetate inhibit vegetative growth and greatly stimulate flowering (156). Snow (187) has emphasized the possibilities of using chemical growth regulators in forestry to control wound healing, bud growth, stem elongation,

sprouting, vegetative propagation, flowering, abscission, respiration, photosynthesis, and other processes. These are challenging prospects. There is enough basic information available to do some of these things already. However, we need much more information on the basic nature of hormonal influences before we can fully exploit the control of tree growth.

WATER RELATIONS

Growth of trees probably is controlled more by water availability than by any other environmental factor (125). When transpiration exceeds absorption of water leaf moisture contents decrease and hydroactive stomatal closure occurs at a threshold value which varies with species. Stomates close earlier in the day for trees in dry soil than for those growing in well-watered soil (117). During the growing season soil moisture often remains at critically low levels for extended periods (96, 98). Fritts (51) found, for example, that in Ohio soil moisture stayed below the wilting percentage from mid-July to mid-August. There is considerable evidence that water uptake and photosynthesis are reduced in drying soil before the wilting percentage is reached (4, 94, 137, 6, 14, 17, 157). Loustalot (137) observed that after a drought rewatering of soil did not restore very rapidly the pre-drought rate of photosynthesis in trees. In Japan Negisi and Satoo (157) noted that photosynthesis of *Pinus densiflora* increased somewhat as the soil dried from slightly above to slightly below field capacity. However, photosynthesis was greatly reduced with further drying of the soil and long before the wilting percentage was approached. It has also been demonstrated that both growth and carbohydrate reserves of plants are greater if soil moisture is maintained close to field capacity than if it is allowed to fluctuate between the field capacity and wilting percentage (224). However, the effect of drought varies greatly with species and sometimes is related to morphological characteristics such as root-shoot ratios. Yurina (227) reported that photosynthesis of several species of trees was reduced in dry soil but the magnitude of the decrease was strongly influenced by depth of rooting. The wide variations among tree species in capacity for root growth (108) undoubtedly play a key role in the differences among species in physiological response to environmental stress.

Water deficits alter both the quantity and character of tree growth. Among the well-known effects of internal water deficits are stomatal closure, reduced transpiration, reduced photosynthesis and starch hydrolysis (118, 125). In addition, water stress alters both the viscosity and permeability of protoplasm. Changes in chemical composition and growth of trees may occur even with mild water deficits. Work with herbaceous plants showed that brief periods of water shortage caused decreased growth, reduction in uptake of nitrogen and phosphorus, and destruction of ribonucleic acid in leaves (53, 54, 55, 56).

Water contents of trees depend on relative rates of absorption and transpiration. Turgidity of tissues does not depend directly on soil moisture or rainfall but rather on factors which control transpiration and absorption (122). Absorption of water lags behind transpiration even in well-watered soils (114, 115). As

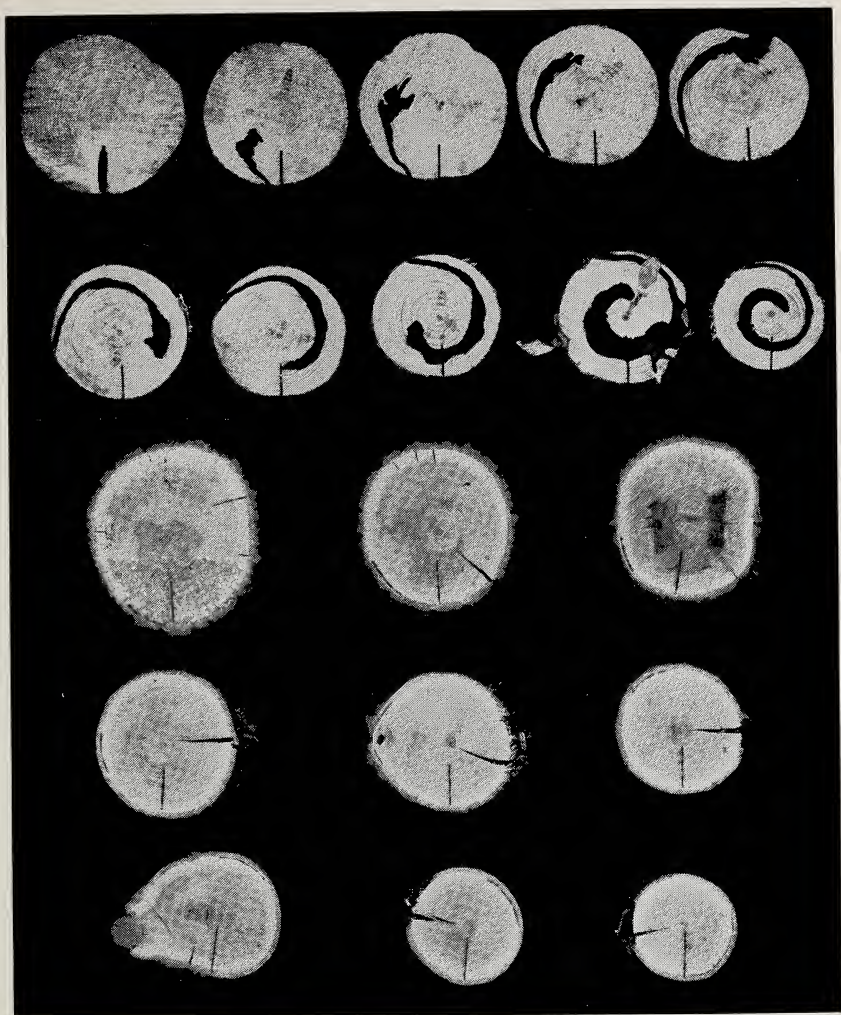


FIG. 2.—Types of water conducting systems in Norway pine (top photo) and northern pin oak (lower photo). Stem sections were made at height intervals of two feet after injection and transfusion of dye into the stem at the base. The radial line indicates the position of the injection knife which was inserted just below the lowermost stem section. Note the confinement of water transport in oak to the stem periphery. The tendency for a spiral pattern of transport in these species should provide good crown distribution of injected chemicals. From Kozlowski and Winget (113).



Kramer (122) points out, water deficits often are caused by excessive transpiration, by slow absorption in dry or cold soils, or by combinations of these. For these reasons greater emphasis should be placed on quantitative measurements of internal water stress in terms of relative turgidity or diffusion pressure deficit in relation to growth (122). In addition, much better methods of evaluating internal moisture stresses need to be worked out. Experiments are needed on specific effects of internal moisture stress on biochemical changes, growth of vegetative tissues, wood quality, floral initiation, and fruit development in forest trees. Paralleling such inquiries we need more field experiments of the type described by Zahner (228) in which moisture control of large trees is obtained by crown pruning, restricting root systems and lateral movement of soil moisture by trenching, by excluding rainwater from root zones by sheltering soil, and by irrigating trenched root systems.

A recent important development in forest tree improvement is the use of systemic insecticides and fungicides Rudinsky (175) cited Reynolds as stating that the development of systemic insecticides is as significant in plant protection as was the discovery of DDT. Several investigators have used systemic insecticides successfully including, among others, Al-Azawi and Casida (2) in control of bark beetles and Giese *et al* (59) in control of balsam gall midge.

In studies of vascular wilt diseases, such as oak wilt and Dutch elm disease, understanding of water transport within the tree and cellular responses to fungus metabolites would permit clarification of host-parasite relations. Pathologists also know that many chemicals and antibiotics are effective as fungicidal and fungistatic agents against fungi in culture, but the nature of their uptake, movement, absorption and adsorption in tissues, conversion, and persistence is practically unknown.

Chemotherapy of trees is clearly identified with water relations since the systemic chemicals generally move up in stems following water ascent in xylem tissues. However, there is great variation between conifers and hardwoods in the amount of stem cross sectional area involved and in the pattern of upward water transport (61, 176, 113) (Figure 2). Rudinsky and Vité (176) showed that patterns of water uptake in unilaterally injected conifers varied greatly among species. Five distinct patterns were described and characterized as spiral ascent, turning right; spiral ascent, turning left; interlocked ascent; sectorial, winding ascent; and sectorial, straight ascent. These differences in patterns of water ascent were attributed to anatomical differences in xylem structure. The most complete distribution of water into the crown was shown by a system of spiral ascent and the least effective by a vertical ascent. These experiments point up the need for continuing research on water movement in trees.

MINERAL RELATIONS

Many studies have pointed up a general infertility of forested areas characterized by deficiencies of all major and some minor elements (60, 125, 163). For example, Gessel *et al* (58) found growth of Douglas-fir retarded by nitrogen deficiency in the northwest; McComb (147) showed tree growth limited by nitrogen and

phosphorus deficiencies in the midwest; Heiberg and White (67) demonstrated potash deficiency of spruce grown in New York State; and Woodwell (225) found nitrogen and phosphorus deficiency to limit growth of pond pine in South Carolina. Over the years tremendous acreages have been planted with trees without regard for or knowledge of mineral requirements of the species involved, even in areas where something was known about soil fertility levels. Although no reasonable estimates are available of loss of increment by off-site planting, the fact remains that much of this loss was avoidable.

As a result of such indiscriminant planting complete plantation failures or depressed growth resulted. Mineral deficiencies effected changes in biochemical and physiological processes and these in turn produced visible symptoms such as necrosis or chlorosis, or other morphological changes. The most common effect of mineral deficiency has been depressed growth often preceded by reduced chlorophyll synthesis and photosynthesis (125). Severe deficiencies have caused death of leaves and shoots. Internal changes have also resulted. Davis (35) found calcium deficiency in loblolly pine to cause reduction in bud size, small leaves, reduction in xylem and phloem, fewer primary and more secondary stem tissues, and reduced cell division in root tips. Other deficiency symptoms have been observed including excessive resin production (88), hypertrophy and death of the cambium (73), and phloem necrosis (181). Many serious mineral deficiency problems are traceable to lack of minor elements. For example, growth of Monterey pine in Australia is severely inhibited by zinc deficiency (186). The effects of mineral deficiencies are complex because of the existing interactions. However, it is reasonably clear that mineral deficiency eventually decreases photosynthesis and translocation of carbohydrates to growing tissues (125).

There is evidence that disease susceptibility in some cases increases under conditions of mineral deficiency. In longleaf pine mineral deficiency increases susceptibility to brown spot needle blight (125). Ibberson and Streater (84) found that trees with white pine blight responded very favorably to fertilizer applications.

Mineral requirements of different species vary greatly (125). Hobbs (74) observed that tip chlorosis was followed by death in several species of pine seedlings grown in magnesium-deficient cultures. However, the severity of the symptoms varied greatly with species. Walker (208) found potassium deficiency in black cherry to show up as a bright red leaf coloration in the margins while potassium-deficient gray birch leaves had chlorotic margins.

During recent years much improvement in tree growth has been observed as a result of fertilization (58, 57, 86, 154, 221). Stoate (192) summarized work on mineral nutrition in Australia and Leyton (134) described fertilization experiments in England. An excellent review of forest fertilization was compiled by White and Leaf (222). Walker and Tisdale (209) recently summarized the scope of research on forest fertilization in the southeastern United States. They stated that approximately 150 substantial experiments dealing with growth and seed production of southern pines as affected by fertilizers are now underway.

As forest tree improvement becomes intensified fertilization will be a useful tool in seed orchards and plantations to increase growth and seed production. In fact, it probably will be imperative to use fertilizers to promote seed development in such high value trees. Allen (3) demonstrated that fertilizers increased cone production in longleaf pine from 1.3 to 13.5 cones per tree. Wenger (217) also showed that seed production could be materially increased with fertilizers.

It is reemphasized that there should be increased research on identifying the specific mineral requirements of forest tree species. Much more information is needed on the internal concentrations of mineral elements with which various species make best growth. Basic data also are needed on the effects of site and climatic factors on the range of internal concentrations at which trees make best growth. Recently Fowells and Krause (48) found in controlled experiments that loblolly pine and Virginia pine grew best when nitrogen was supplied at a constant rate of from 25 to 100 ppm. They also found that a supply of only 1 ppm. of phosphorus was adequate for the growth of these trees. Tamm (196) reported that best diameter growth of Scots pine was related to a foliage nitrogen content of 2.0 to 2.5 per cent. These are meaningful data but we need to know much more about mineral requirements of trees at various ontogenetic stages. With all the support for fertilization research in the field probably the most useful information will accrue from diverting some of the effort to very basic physiological research in controlled-environment facilities.

Especially needed are experiments which will separate the importance of mineral relations from other factors in the ecological nexus which controls growth. A good example of the type of research needed is that of Hellmers *et al* (71). In this study response of chaparral trees and shrubs to soil fertilization was tested in both the laboratory and field. In the laboratory soil fertility was improved by adding minerals to soils while holding all other conditions favorable and constant. Field trials based on the laboratory results were then conducted to determine if mineral deficiencies were overshadowed by other environmental factors.

In the laboratory experiments a five-factor factorial design was used in the fertilizer treatment with each action and interaction replicated. Water quality and movement through the soil mass were controlled. Uniform experimental plant material was obtained by growing from seed and discarding the extreme plants. The plants were distributed through the fertilizing schedule so that a statistical analysis showed the plants of any treatment and control to be from a homogeneous population. When analyses of dry weights of harvested plants were made significant interactions were found. Therefore the responses of individual factors were separated from the interaction response.

In the field experiments it was shown that growth was related to water deficiency. The relationship between soil fertility and natural supply of water was then tested. Plots were treated with nitrogen, phosphorus and combinations of these. Nitrogen alone stimulated growth but nitrogen and phosphorus in combination failed to produce additional growth increase. It was concluded that lack of available water in the field became critical for growth before all the naturally

available phosphorus was used by the plants. These studies emphasize the usefulness of combining field experiments with laboratory techniques.

SEED PHYSIOLOGY

Reproduction of forests and production of nursery stock often are difficult because seeds of well over half the species of forest trees exhibit dormancy to varying degrees. The nature of seed dormancy varies greatly. In some species seed dormancy is caused by seed coat impermeability to oxygen or water, and in others by conditions in the embryo itself. The embryo may be immature or, in morphologically mature embryos, there often is a deep-seated physiological inability to germinate even under the most favorable environmental conditions. Embryo dormancy often is attributed to inhibitors in the embryo or surrounding tissues. For example, in birch an inhibitor has been found in the pericarp (12), and in northern red oak in the cotyledons (33). Many different compounds appear to act as natural germination inhibitors including ammonia, hydrogen cyanide, ethylene, essential oils, alkaloids, unsaturated lactones, and unsaturated acids (47). Germination inhibitors have been found in almost all structures which act as seed coverings or embryo coverings within a seed.

Dormancy of many seeds can be broken by pre-germination treatments such as soaking in acid or water, stratification or seed coat removal. However, the efficiency of these treatments varies markedly with the degree and kind of dormancy. Our inability to break embryo dormancy in many species may be attributed in large part to the dearth of knowledge of the specific biochemical changes which occur during the break of dormancy.

The energy requirement for germination onset is met by increased respiration (202). Oxygen limitations to the embryo often exist (195). Respiration of eastern white pine seed can be increased by surrounding intact seeds with a high oxygen atmosphere, or by divesting seeds of seed coats (104) (Figure 3). Both treatments increase the partial pressure of oxygen around the embryo which in the intact seed may be low enough to interfere with necessary oxidative reactions. Pollock and Olney (169) suggested that one cause of breaking of dormancy in cherry seed may be increased availability of energy to the embryo because of an increase in supply of phosphate acceptors.

Since the germinative process appears to be linked to respiratory activity after water is imbibed, efforts to stimulate oxygen uptake in dormant seeds may prove useful. For example, hydrogen peroxide pretreatment has been found to increase germination in several species including Douglas-fir (28, 182) and eastern white pine (101).

Ching (28) partitioned the normal course of germination of Douglas-fir seed into four distinct stages:

Stage 1. The imbibition phase, which usually is short and characterized by almost linear increase of respiration and water uptake. This phase usually provides adequate hydration for enzymatic activity.

Stage 2. The antephase or mobilization phase, which is characterized by a constant respiratory rate and respiratory quotient, and a temporary cessation of further water uptake.

Stage 3. The pre-emergence phase, which is characterized by a gradual increase of water uptake and respiratory rate, and in rapid rise of the respiratory quotient to approximately 1.15 at the time of radicle emergence. This stage is the active mobilization of the energy source and cellular components preparatory to later stages of germination which are accompanied by growth in terms of cell number, cell size and tissue differentiation.

Stage 4. Increase in respiration and water uptake phase. Although respiration and water uptake are increased the respiratory quotient declines in the seedling and attached, partially-digested endosperm. This stage apparently indicates a remobilization for cotyledon emergence.

Ching found that seed soaked in hydrogen peroxide failed to exhibit Stage 2 (constant respiration, consistent respiratory quotient, and cessation of water uptake). The third stage was considerably shortened, while the fourth stage was similar to that of the untreated controls. Oxygen and water uptake were substantially higher in hydrogen-peroxide-treated seeds than those of the controls. This probably indicates that conversion of fats to reserve carbohydrates was higher in hydrogen-peroxide-treated seeds and more synthesis of cellular components took place in them than in untreated seeds. Hence, it appeared that hydrogen peroxide stimulated germination of Douglas-fir seed by accelerating respiration during the antephase of mobilization. This work is cited in some detail as an example of an approach useful in understanding the blocks to germination in different seeds. After the nature of germination is better understood for seeds of different species the blocks to germination can then be attacked. In addition, more information is needed on physiological indices of seed maturity. As Rediske (170) pointed out, knowledge of seed maturity would make possible processing of only mature seed, full extension of the harvest season, and storage of mature seed under optimal conditions.

PHYSIOLOGICAL IMPLICATIONS IN SILVICULTURE

Many practicing silviculturists decry the need of a sound foundation of basic information on which to build a rational system of silviculture. For this reason more effort should be directed to a continuing study of the physiological implications of silvicultural techniques. Many speculative concepts of the physiological basis of response to thinning, pruning, and use of herbicides, for example, should be subjected to rigorous experimental scrutiny, under controlled conditions if possible. Over the years it has been assumed that in competition trees die from lack of photosynthate, but there is evidence that auxin deficiency and other considerations also play a significant role (107). It has been assumed that lower branches which prune naturally die from starvation, yet the water and hormonal relations have not been satisfactorily evaluated. For intelligent pruning programs we need to know which branches contribute to stem growth, and how much, as

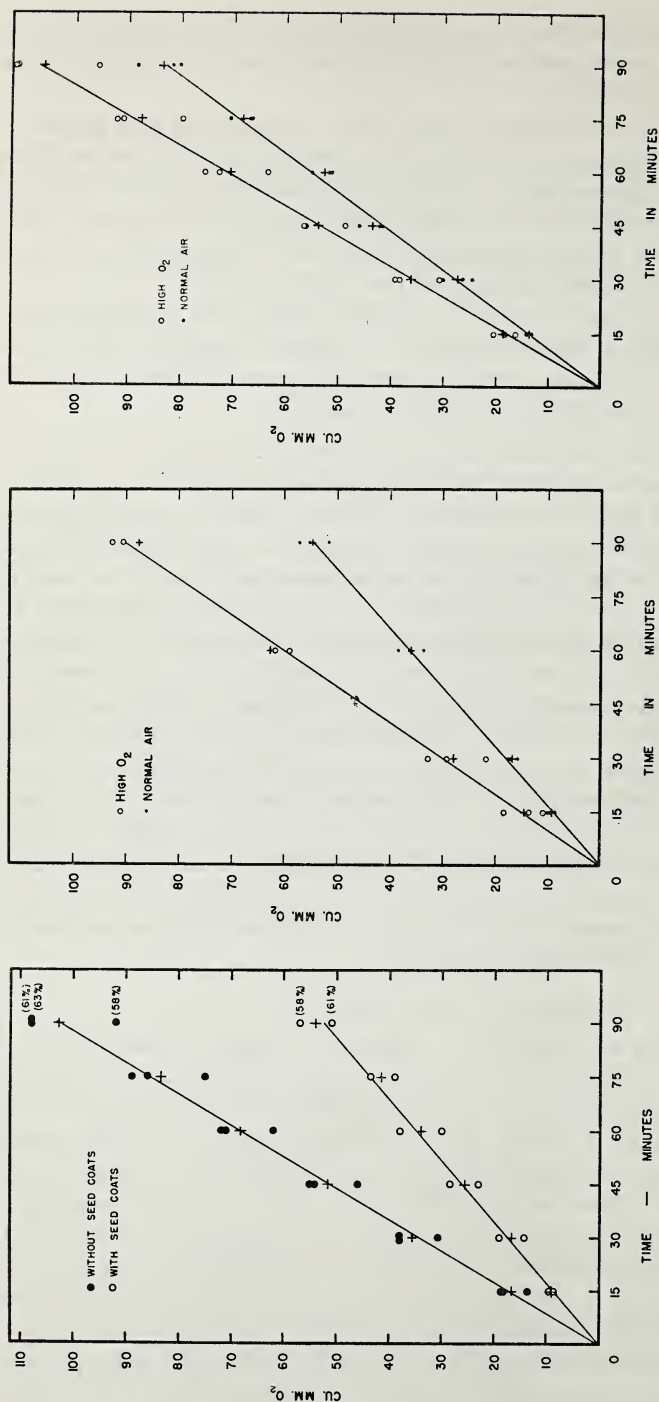


FIG. 3.—Effect of seed coats on respiration of eastern white pine seed. Ordinate values represent respiration rates, as oxygen uptake. The abscissa values represent time. *Left graph* shows respiration of intact seeds and seeds without seed coats in air. Moisture contents of seeds are given in parenthesis. *Middle graph* shows respiration of intact seeds in air and in

a mixture of 80 per cent oxygen—20 per cent nitrogen (designated as high O₂). *Right graph* shows respiration of seeds without seed coats in air and in a high oxygen atmosphere. These experiments emphasize that seed coats are a barrier to oxygen uptake of internal seed tissues. From Kozlowski and Gentile (104).

well as which branches are parasitic and under what conditions. In this connection the statistical technique of Labyak and Schumacher (129) might be useful. They demonstrated that in loblolly pine the average contribution of a single branch to the cross sectional growth of the main stem depended on branch location and number of branchlets. A branch with less than three branchlets in the lower half of the tree length, or a branch with less than five branchlets in the lower quarter of tree length contributed nothing to growth of the main stem.

A good example of how a knowledge of physiology can be put to practical use is in the work of Wilcox *et al* (223). They first studied cambial activity of several species of gymnosperms and angiosperms. Later in using arsenic compounds for chemical debarking they found the gymnosperms peeled best if treated immediately after the natural sap peeling season began, while angiosperms peeled best if treated two to three weeks after the beginning of the sap peeling season. The significance of physiological considerations in forest production can also be illustrated by a discussion of the modern use of herbicides in forest stands. There is considerable evidence that in the future herbicides will be considered indispensable for management of large forest areas (100). The tremendous usefulness of herbicides in stand regeneration, release of conifers and crop trees, brush control, stand improvement following harvest cuts, plantation establishment, production of nursery stock, firelane and utility line maintenance, and control of tree diseases, has been amply demonstrated and documented (100). Herbicides are indeed an important silvicultural tool for restoring forests which show much lower productivity than they should because of the presence of inferior species, wrong density of stocking, and low quality trees.

In releasing conifers with herbicides we must keep in mind the physiological characteristics of all the species in the stand. Conifers which are growing actively at the time of herbicide application may be killed by even light applications. In the Lake States foliage sprays caused injury to new growth of white spruce until mid July; to red pine, white pine and Norway spruce until August 1, and to jack and Scotch pine until August 15 (5). To time the applications of herbicides it is important to know that some species may grow twice as long as others (96, 98, 100, 110, 111, 125). In addition, the tendency of some species to form lammas shoots in late summer from bursting of current-year buds (146) may pose a problem.

In intensive management the removal of individual trees with herbicides to control stand composition and quality may kill adjacent crop trees by "backflash" or translocation of herbicides through root grafts (16, 32). The wide occurrence of natural root grafting in many species of forest trees is well known (131, 133, 226, 127, 16, 102, 103). Bormann (16) demonstrated movement of water, minerals, foods, dyes and poisons between trees through natural root fusions. Hence, basic studies of translocation are needed to evaluate the significance of root grafting and the actual amount of parasitism which exists among trees of different species.

Still other physiological considerations are involved in use of herbicides. In most hardwood stands a really efficient elimination of competing hardwoods involves both killing of tops and prevention of resprouting. But with many undesirable species this is not easily done. Many herbicides cause excellent top-kill of hardwoods but few will kill tops and also prevent resprouting in certain seasons (210). Application of some basic physiology is exceedingly useful for there is much evidence that sprouting vigor is correlated with carbohydrate reserves. In general, sprouting is least abundant from stumps of trees cut in early summer when trees have leafed out and exhausted carbohydrate reserves, and it is greatest from stumps of trees cut in the dormant season (29, 125). Aspen and other species sprayed with herbicides at the time of full leaf development seldom sprout, but they develop suckers and sprouts readily when sprayed at other seasons (5, 193). Here then is an example of how basic information on carbohydrate cycles and sprouting can be applied in a conifer release program. It might also be added that we need basic physiological research to find a way to artificially stimulate dormant buds so they will be active at the time of herbicide application rather than later.

Some species are difficult to kill with any herbicide because leaf absorption is inhibited by a thick cuticle (20, 21). Hence, more research is needed on cuticle penetration of herbicides and factors influencing their effective translocation. Experiments also are needed to determine herbicide formulations which are most efficient on different species. Experiments show that 2,4-D moves with carbohydrates in phloem. Therefore, efficient photosynthetic activity assures good herbicide distribution. An understanding of the effects of environmental factors on photosynthesis would aid in developing refined techniques of herbicide applications.

In this brief reference to use of herbicides there was consideration, either directly stated or implied, of seasonal sprouting, bud dormancy, translocation of water, minerals, hormones, and carbohydrates, and photosynthesis. All of these are physiological matters which inescapably must enter our consideration of forest production.

THE NEED FOR BASIC PHYSIOLOGICAL RESEARCH

Implicit in the challenges of forest production for the future are needs for training more forest physiologists. Only the specialist can be expected to provide solutions to difficult research problems. Inevitably forestry education will be confronted with the problem of providing a stronger background in chemistry, physics and biology for the accomplished undergraduate destined to do graduate work in preparation for a research career. At present, general forestry curricula require a sampling of a wide spectrum of professional forestry courses. Many of these are not a substitute for the basics for specialized research training.

Over the years the climate in forestry has not been exactly conducive for basic research. Accumulation of fundamental information that would improve forest production often has perhaps inadvertently, been restrained by an administrative

climate which was somewhat hostile to fundamental research because of its alleged impracticality. Richardson (173) cited the case of a research director who found it easier in his budget to "indent for a bulldozer than a test tube." One accomplished investigator who did classical basic research on mineral nutrition of trees some thirty years ago dropped his work completely for failure to find sponsorship. Fortunately, however, the situation is changing rapidly and in the right direction. The last decade has seen basic research laboratories supported not only by universities, but also by federal agencies and industrial concerns as well. Forestry curricula are emphasizing more physiological training and forest physiologists are now in demand. Furthermore, the several recent conferences devoted exclusively to forest physiology and the accelerated flow of research papers in this field indicate growing realization of the importance of physiological research as a prelude to wide practical application (119, 194, 173, 148). Kramer (119) pointed out as a parallel that medicine made its greatest progress when it began to concentrate on biochemistry and physiology. Many of the most useful applications of science have turned out to be outgrowths of fundamental research that was not designed *a priori* to yield immediately applicable information (95).

SUMMARY

There is agreement on the need for handling forests to produce trees of selected species, with good form, quality and rate of growth, as well as resistance to disease and insects. Meeting these objectives will require increased emphasis on physiology of tree growth. Physiologists can contribute to tree improvement by identifying and characterizing the processes controlling growth and demonstrating how heredity and environment influence various physiological processes. The importance of internal processes in growth control can be emphasized by time-lag responses of trees to environmental changes.

Physiological implications in forest growth are reviewed and some of the more important research needs emphasized. Especially needed are studies of photosynthesis in relation to growth as well as studies on the relation of carbohydrate production to its utilization in the tree. In the field of hormone physiology the need for basic studies on the mechanism of flowering and the relation of growth regulators to wood quality is stressed. Water relations research also is needed especially on methods of evaluating internal moisture stresses and on water transport in relation to chemotherapy. In addition more research is needed on mineral requirements of trees and on the mechanism of seed dormancy.

In order to have intelligent silviculture more attention should be given to physiological implications of silvicultural practices such as thinning and pruning. Reference is made to need for knowledge of sprouting, bud dormancy, translocation of water, minerals, hormones, and carbohydrates as well as factors controlling photosynthesis for efficient use of herbicides in handling of forests. Improvement of forest production will require more trained physiologists and increased support for research on basic physiology of trees.

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Silvicultural Considerations

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This symposium on challenges in forest production includes a consideration of soils, physiology, silviculture, and forest management. My subject is silviculture, but before starting I think it will be helpful to relate the four above fields to each other. Then if I stray a little from my assigned subject, the overall perspective will remain intact.

The quality of the site (the soil and the climate) determines the potential or upper level of forest production. Soil, air, water, and sunlight are sources of the basic materials for growth. The processes by which trees use these basic materials, and thereby live and grow, are covered in the field of forest physiology. Silviculture is, essentially, the manipulation and culture of the forest cover for man's purposes by using an integrated knowledge of soils, physiology, silvics, and genetics. Forest management is concerned with the business and economic aspects of protecting and growing forests. I will discuss silvicultural considerations and try not to get too far into related fields.

Silviculture includes (1) genetic improvement of trees, (2) recognition and use of superior races or strains of trees, (3) control of forest species composition, (4) methods of obtaining desirable tree reproduction, (5) methods of establishing forests by artificial means, (6) control of yield and quality of products desired, (7) systems of harvest cuttings for sustained yield, and (8) the handling of forests and forest lands for multiple uses. Each of these subjects contain challenges for American forestry.

PRINCIPAL BASIC TO THE SILVICULTURAL CHALLENGES

Perhaps the most important general challenge to foresters is understanding the basis of our profession, i.e., the art and science of managing forests for man's needs. This will require a long time and much more basic research. Elsewhere (Minckler, 1958) I have discussed some concepts basic to the practice of hardwood silviculture. Here I will discuss some of the factors basic to the silvicultural challenges in forest production with the hope that these challenges will be better understood.

It has been recently reported by Hellmers and Bonner (1959) that forests under near optimum conditions can "capture" 2.0 to 2.5 per cent of the total visible light energy available. It is stated that this rate of efficiency is similar to that of field crops, and the authors conclude that these percentages roughly approximate the maximum capacity for all plant cover. While a ceiling on efficiency undoubtedly exists, because of the nature of the photosynthetic process and the

amount of carbon dioxide in the air, there is plenty of room below the ceiling where a forester can manipulate forest stands and sites for better production.

At each particular place on the earth there is a secondary or local ceiling on wood production dependent on site quality and climate. This ceiling on productive capacity may be vastly different among places. Generally, foresters have to accept these ceilings although in some cases the site quality can be altered. The job of the forester, and more particularly the silviculturist, is to know how to channel the greatest possible amount of energy flow per unit of time into the *kind and quality of forest values desired*. This is the overall challenge to our profession.

WAYS TO INCREASE TOTAL WOOD YIELD

Total wood yield can be increased by silvicultural means and by changing the quality of the site. This has been called "creative silviculture" (Ostrom, 1959). We can *manipulate the forest cover* to increase yield in the following ways:

1. By changing the density and structure of the forest. However, this does not alter the total amount of dry weight of wood produced within a wide range of density and structure. Manipulation of the forest within this range is the heart of yield and quality control.

2. By increasing the ratio of photosynthesis to respiration of crop trees and the forest stand as a whole. This is closely related to changing density and may be accomplished by reducing the amount of live tissue where respiration is high in relation to the photosynthate produced. (Our knowledge concerning this, however, is very meager.)

3. By making genetic improvement in the tree species grown. Insofar as this increases the total dry weight of wood produced on a given site, it results in greater efficiency of the tree for utilizing the basic ingredients available to it. In some cases only the quality or form of wood produced may be improved.

4. Through the use of new or different species, strains, or races of trees on particular areas which give greater total wood production or improved quality and bole form.

Ways of *changing forest site productivity* to increase wood yields are:

1. Restoring lost productivity of abused sites by protection from fire, grazing, and abnormal erosion and the use of species adapted to the soil and climate.

2. Improving the productivity of the site by cultivation, fertilization, or irrigation. These are usually expensive tools but will probably be used more and more in the new "creative silviculture."

3. Eliminating forest floor vegetation that competes with trees and thus detracts from wood production. Obviously this cannot be used effectively during periods of natural regeneration or where it conflicts with other desired uses.

There are, then, various ways to increase the production of wood from forests. There are challenges associated with all of them. The classical method, and the one used almost exclusively until the last two or three decades, is to control net yield, quality, and form of wood grown through cultural techniques. These include

site preparation, weedings, release cuttings, improvement cuttings, thinnings, density-structure controls, harvest cuttings, and artificial regeneration. These practices are still the heart of silviculture, but newer concepts and methods are beginning to receive well-justified attention.

SILVICULTURAL CHALLENGES

Silvicultural challenges should be considered against the background of diminishing virgin forests and the expanding world need for all kinds of forest products and benefits. Three things are evident: First, we must *grow* our timber rather than *find* it; second, our silviculture must be intensified; and third, we must learn how to accommodate the demands for different uses made of the forest. (In the Forest Service we refer to the latter as "multiple use.") With these needs in mind, let's name specifically the challenges that face us in silviculture and discuss each one briefly.

1. *Silvical characteristics of trees and forests.* We should face the fact that we do not adequately understand the behavior of individual trees or aggregations of trees. The biological and physical basis for tree behavior is covered in the subject of tree physiology. However, the outward response of trees, especially the interaction of trees within stands to each other and to their environment, is in the field of silviculture. This is akin to human sociology except that trees lack mobility and must prosper or die in one specific spot in direct competition with other trees and plants. Therefore, ecological laws apply in a rigid manner to trees, and foresters must know and understand these laws before they can properly manage trees and forests for the greatest benefits to people.

Some recent research in southern Illinois on light and soil moisture in hardwood stands illustrates the attempt to gain a better understanding of the relations between light, soil moisture, and the development of reproduction. We now know the total amount of light received in forest openings of different sizes for day-long periods and how this varies by aspect and time. For example, the center of openings with a diameter equal to the height of surrounding trees receives in June about 45 per cent of full day-long sunlight on both northerly and southerly aspects. In September north slope openings of this size receive only about 10 per cent while south slope openings receive nearly 60 per cent of full sunlight in the open. In June and early July available soil moisture in both small and large openings is high, often 15 to 20 per cent greater than under the canopy, but in late summer soil moisture often approaches the wilting point throughout the forest. This coincidence of good light and soil moisture conditions on north slopes and of high radiation and low soil moisture on south slopes helps explain the observed differences in composition and behavior of reproduction.

2. *Rehabilitation of existing forests.* A large portion of the forests of this country are unmanaged (Forest Service, 1958). By unmanaged I mean that past cutting has been done without regard to appropriate silvicultural practices or that the forest is still in its natural condition. The cut stands characteristically have low stocking, with poor diameter distribution, undesirable species composition,

and a high percentage of low-quality and cull trees. The virgin stands are usually over-stocked and, because of heavy mortality, net growth rate may be close to zero. A high-priority task (after protection) is to put these forests in a dynamic condition by removing the overburden of cull, low-quality, and mature trees (Minckler and Hosner, 1956). This, together with forest protection, is the highest priority *action* program needed in American forests today. Although the costs-and-returns aspect is a forest management consideration, the methods used in stand rehabilitation and the biological response of the trees and forests are a part of silviculture.

On our Kaskaskia Experimental Forest many hardwood stands have received a rehabilitation cutting treatment. One example will suffice. An upland hardwood stand of 4,200 board feet volume and 78 square feet basal area per acre was reduced to 2,000 board feet and 48 square feet basal area by a rehabilitation treatment. All merchantable trees not considered good growing stock were cut for sawlogs, and all cull trees were killed. Eight years later the volume was 4,700 board feet and the basal area 57 square feet per acre. This net growth of 335 board feet per acre per year contrasted with a net growth of about 150 board feet before the treatment. In addition, the average quality of the stand was greatly increased by the removal of cull and low-quality trees, and reproduction developed rapidly in the openings.

3. *Genetic improvement of trees by selection and breeding.* The objectives of genetic improvement are to develop more photosynthetically efficient trees, to produce more usable trees, or both. In the long run the possibilities are great, but we can only partially surmount the limitations on production made by site quality and climate. Probably the greatest gains can be made in quality characteristics such as improved tree form, bole characteristics, and wood properties. Important gains may also be possible in developing trees resistant to diseases and insects.

One weakness of a program of improving trees by genetic means lies in man's imperfect knowledge of what he will want in the future. Genetic improvements in trees, especially as a means of increasing wood production, will usually require many years. Programs pointed toward increasing the harmony between tree species or races and particular site and climatic conditions are basic, and the need for them is evident. The same is true for inheritance of the basic components of wood structure such as cell wall thickness, cell size, and fiber length. Aside from these, we should select our genetic goals with great care.

4. *Introduction of new species or strains.* We cannot always assume that native species of trees will be the most productive for our needs. It is true that they usually are, but exceptions exist, especially in regions that have only a few desirable species. The selection of better species for specific areas remains a challenge but should be approached with caution and scientific regard for the environmental requirements and disease and insect resistance of the species being introduced. A "shotgun" approach of testing many species may accidentally succeed but usually is inefficient. Generally, species to be introduced on a trial basis should be native to a region having a similar climate.

Examples of successfully introduced species include Monterey pine in South Africa and various exotic conifers in the British Isles. Loblolly pine from the northern part of its natural range promises success as a fiber crop in the southern part of the Central States. More often, however, introduction of non-native species has been a failure.

5. *Increasing total wood growth by increasing effective photosynthesis.* Theoretically, the elimination of living tree tissue where photosynthesis is low in relation to respiration would increase the net growth of woody material (Baker, 1950). Branches with low rates of photosynthesis use most of the photosynthate produced locally just to stay alive and to add wood to themselves rather than to the bole. In addition, these members use water, nutrients, and possibly shade smaller trees or reproduction. In some cases it is possible that branches may "borrow" photosynthate from the remainder of the tree. This behavior explains why lower live branches can usually be pruned without loss of bole growth. Long branches or trees with a small area of foliage have a low leaf area in proportion to the respiring live tissue. Old trees have a high proportion of respiring tissue in relation to chlorophyll-bearing tissue, thus causing decreases in net growth (Hellmers and Bonner, 1959). Forest floor vegetation (often unwanted by man) uses water and nutrients that would otherwise go to production of usable wood.

Although we are cognizant of a variable relationship between photosynthesis and respiration, we still do not know how to control it to increase wood production. Fortunately, much of what we do in thinning, improvement cutting, and pruning tends to eliminate the inefficient trees and branches; but we need to learn how to do this in a more specific and positive way.

6. *Yield and quality control of timber stands when products are used as unmodified wood.* In yield and quality control we are concerned with producing maximum yields of wood of the highest quality for the products wanted: For example, wood suitable for panelling, furniture, veneer, structural members, and specialized uses. Put another way, we want to channel the basic photosynthetic energy into *usable* form in the shortest time. Knowledge and "know-how" must start with reproducing the forest and continue through harvest cutting. This requires understanding the behavior of individual trees as well as their behavior when they grow together in stands. Many-aged stands of mixed species are obviously more complex than even-aged pure stands; and, possibly, for that reason the former have been studied very little.

Trees growing together affect one another profoundly. Foresters talked about "normal" stands as a desirable goal. Now we know that "normal" stands are rarely found, are static in nature, and are not what the forest manager wants at all. Even so, we still do not know the best stocking and tree-size distribution for specific species, sites, and products that will give maximum sustained returns. We don't know how even- and many-aged stands would differ in this regard. Our information on optimum¹ stocking-structure for mixed many-aged stands is piti-

¹ Foresters commonly use the term "optimum stocking," but it is understood that there may be several optimums corresponding to different conditions or levels of management.

fully small. We can make some reasonably good estimates, but we do not fully understand how trees growing in groups (stands) behave. When we have this information, the quality and quantity of timber products can be increased significantly.

A start toward obtaining these answers for uneven-aged hardwoods is being made in southern Illinois by the establishment of 60 one-half-acre experimental plots in which both the stand stocking and structure are varied. All components of stand growth are being studied in relation to stocking-structure, species composition, and site. A few sample results will illustrate the work. Based on six-year-growth results for one replication, net volume growth on low-stocked stands (40 square feet basal area) was 75 per cent as much as for high-stocked stands (80 square feet basal area). Stands with large-tree structure grew in net volume about 75 per cent as much as stands with relatively small-tree structure. Ingrowth was higher on poorer sites and in stands with smaller trees. Except for the untreated check plot, mortality did not occur on the better sites but did occur on the heavier stocked stands on poorer sites. Volume-growth rate expressed as simple interest ranged from 6.5 per cent for low-stocked stands with smaller tree structure to 2.0 per cent for high-stocked stands with larger tree structure.

We know even less about the behavior of individual trees than of stands. Has anyone ever watched a sapling grow to maturity and recorded the pertinent data associated with growth? What happens to the crook in the bole of a three-inch sapling? How many of the bole defects in a six-inch tree are still visible when the tree is sixteen inches, and how many new ones have developed and why? How can bole defects (mostly from bole branches) be greatly and effectively reduced? Is artificial pruning an effective and economical way of reducing defects in hardwood logs? How is tree growth related to crown and other tree characteristics, and what growth rate is best to produce the grain and wood density needed for particular products? Such questions could be asked almost indefinitely. In short, the challenge is to obtain the information needed to understand and control the factors which determine the quality of trees for particular products.

Examples to illustrate the extent of the bole defect problem can be given. The average pole-sized black and scarlet oak in well-stocked but unmanaged upland stands in southern Illinois had about twenty bole sprouts per ten feet of bole. White oak had about half as many. Small sawtimber of black and scarlet oak had fourteen total defects per ten feet of bole in the butt log and twenty-four in the upper logs. Larger trees and different species generally had fewer defects. The number and kind of bole defects differed among places, sites, species, tree size, and in position on the bole.

7. *Yield and quality control for production of wood as a raw material for re-processing.* The challenge of growing wood as a raw material is to produce the maximum volume and weight of wood of desired characteristics per unit of time. To do this we must determine the optimum stocking-structure of the stand and the correct rotation length to give top yields of wood material by species and sites. This has sometimes been called "cellulose forestry." Rotation lengths would be

much shorter than for "sawlog forestry" and methods of obtaining reproduction should be modified because trees would be younger and smaller at time of harvest. Furthermore, quantity yield would need to be coordinated with quality of the wood produced. Wood quality characteristics could include chemical composition, fiber length and strength, and density.

Improving quantity and quality of the wood might well result from improving the genetic strains of trees. For example, unpublished work by Dr. Steve Boyce at our Carbondale field office indicates that 30 to 40 per cent of cottonwood fiber-length variability is inherited; as yet we have no control over this. But, aside from genetics, we do not fully know the environmental factors and silvicultural practices involved in the most efficient production of wood for reprocessing.

8. *Changing the site quality.* In agriculture it is standard procedure to modify site quality by artificial means. In forestry, site improvement is still a challenge. Forest sites can undoubtedly be improved to some extent by fertilization, irrigation, and cultivation, to name the chief methods; but little of this has been done. However, the "farming" of cottonwood on alluvial lands in the South using ground preparation, fertilization, cultivation, and even irrigation has already started on a small scale and promises to expand rapidly.

Conversely, sites can and have been depleted by excessive burning, erosion, excessive oxidation of organic matter, or excessive accumulation of raw humus. Some European foresters (Plochman, 1960) believe that several generations of "unnatural" pure even-aged stands can result in great site deterioration, and they have many examples to prove it. In America forestry is young, but examples of site depletion by excessive burning and grazing followed by erosion are commonplace. The millions of acres of abandoned old fields requiring artificial regeneration constitute a site challenge in themselves. Eroded, compacted woodland soils are also widely prevalent though less spectacular.

9. *Development of yield tables for managed stands.* We have no proven, accurate yield tables for our *managed* forest stands. Furthermore, we have no yield tables or growth-prediction equations of any kind for managed uneven-aged stands. We operate by estimates and educated guesses. To develop the needed yield tables is a tremendous job and will require decades of forest management and research to complete. Not only do we need yield tables by species, sites, stocking, and systems of silviculture, but also we need accurate and convenient units of measurement for expressing stocking, structure, growth, and yield. Both forest managers and silviculturists need this information. The humiliation to our forestry profession caused by these deficiencies makes the challenge even more acute.

10. *Sustained yield and multiple use.* How do we integrate a sustained high production of quality wood with other compatible uses of the forest? How do we accomplish really sustained yield in the first place? We have not been practicing forestry in this country long enough to find out. It involves obtaining reproduction, controlling density and quality in the stands, regulating cutting cycle length, and improving methods of harvest cutting. We must learn how to sustain forest yields over many rotations without deterioration of the forest or the site. Then we must

learn how to modify these practices to accommodate wildlife, watershed, and recreation uses which are already making pressing demands on our forests. This is an increasingly important challenge to foresters. For example, group-selection silviculture in most hardwood types meets the requirements for successful reproduction and good productivity without the exclusion of watershed, recreation, or wildlife values. However, excessive recreational use in such stands would lower or eliminate forestry values. Likewise, excessive deer browsing would make impossible the regeneration of tree species in the openings. This has happened. We must find a balance between the various uses on forest areas or abandon sustained yield and multiple use on these areas. Will the tidal wave of man's needs and desires overwhelm the forests before we learn how to cope with it? We foresters must show the way so that the people can act!

A FINAL WORD

We are celebrating the Fiftieth Anniversary of the College. The forestry profession in America is older than that. How does it happen, then, that there are so many challenges, so many unsolved problems? Have we been remiss? Regardless of the answers to these questions, we have work to do; and we must get on with the job by: (1) learning and understanding the basic biological and economic principles of our profession, (2) developing "know-how" to do the required jobs, and (3) applying this know-how to our forest resources.

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Soils Considerations

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The challenge to increase forest production in the years ahead logically includes a consideration of the soil as part of the dynamic ecosystem operating in every forest community.

Those concerned with the relative significance of the various factors which comprise a forest site, as well as those primarily concerned with creating wealth from the growth on that site, are becoming increasingly aware of the complexities of the "organism" with which they are working. Recently Ovington (1960) in England and Hills (1960) in Canada have elaborated on the ecosystem concept to show the importance of using the whole site approach to not only site classification, but to the establishment of a logical basis for silviculture and management.

The soil is the basic medium on which vegetation and climate can produce forest growth; depending on the skill of the silviculturist and manager to create forest wealth. The fact that this natural resource, the soil, can be manipulated and converted within limits to suit the needs of a crop is well illustrated by our modern successes in agriculture in spite of Thomas Malthus and his theory.

We can accept with reservation the biochemical calculation of the limits of photosynthetic potential on any given acre. Even this assumption requires some hedging because sooner or later we will come to the accomplishment of planetary engineering (Nourse, 1960)—including man-made changes in climatic conditions affecting whole regions if not the entire earth. We must, in fact, come to this stage of environmental control if we are ever to achieve man's dream of colonizing the planets or what may lie in outer space.

So who can say we have achieved anywhere the ultimate in productivity of any species? Who knows what the optimum combination of light energy, temperature, water, nutrients, genotype, and silviculture is required to achieve the maximum productivity for white pine or red oak or Douglas fir? In controlled artificial environments the tomato plant has been made to yield over six times its maximum under natural conditions. In California look at the case of Monterey pine, an unimpressive producer in its natural range, yet literally exploding in growth in a more favorable environment. And again this same species, when lacking a handful of available zinc in the soil per acre, becomes another exotic struggling for existence on an "unproductive soil."

If this seems to be indulging in flights of fantasy—way out—beyond the realities of forest economics, it is only to emphasize that there is a real challenge in forest production ahead. The charge to explore what the soil scientist can do in concert with the physiologist, the silviculturist, and the forest manager seems best served by offering examples of work now being done by forest soils specialists

to determine the best natural soil-species combinations, and to assess, whenever possible, the soil environment which comes closest to the optimum requirements of a particular forest for growth.

In the years ahead we should, as pointed out by Kellogg (1958) be concentrating on the better or more productive sites for forest production. With the constantly shrinking agricultural land base, at least in this country, there will be more and more of the so-called "better" soils available for forestry purposes—but how to recognize the better soils for forestry. Certainly these are not always the same as the "better" soils for agriculture as has been emphasized by Wilde (1958), who points out that in Wisconsin the highly desirable—at least for farmers—Miami soils of medium texture support at best 12 M.B.F. of hardwood forest at 100 years whereas coarse glacial outwash may produce four times the yield of white pine in the same rotation. This type of comparison does, of course, violate the ecosystem concept by categorizing good versus poor soils without integrating all of the regional site factors including mainly the differences in potential evapotranspiration in the southern part of the Lake States versus the northern part, as well as the differences in the distribution pattern of precipitation. All of these do profoundly affect the key to site productivity for forests—available water.

In the discussion which follows no attempt is made to be complete in coverage, but to illustrate by example the ways and methods by which soils may be managed by foresters.

SITE CLASSIFICATION AIDS FOREST PRODUCTION

The oldest and most generally accepted type of soils investigations related to forest productivity are those concerned with classifying forest sites in terms of productivity or suitability for species establishment. Coile (1952) and those who have followed his techniques (Carmean, 1954; Zahner, 1958a) have done a great service in devising simple and sometimes single factor correlations of soil variables with site potential. This technique, best adapted to pioneer species on mature soils with distinct and easily measured soil horizons, has not been too successful in the region of glacial soils or immature soils. Others (Deardorff and Lloyd 1958; Van Eck and Whiteside, 1958) have tried to use regular or modified soil survey designations as an index of productivity for forest growth. This technique also has been of limited applicability, of greatest use with modern soil maps designated on the basis of deeper profile investigations and in areas of relatively homogeneous soils. One key to the successful use of this approach is the judicious grouping of soil associations by soil scientists in cooperation with foresters into logical divisions based on species requirements.

Recently, the greater significance of fractions within the sand separate (.05-1.0 mm), particularly the fine (0.1-0.25 mm) and the very fine (.05-0.1 mm), sand on the readily available water supply of soils has been emphasized by soil scientists. An examination of the relative water supplying power expressed by

readily available water (water released between 0.06 and 6.0 atmosphere tension) is shown in Table 1.

Table 1: Readily available water holding capacity (between 0.06 and 6.0 atmosphere tension) in upper 66 inch profile of soils of various texture: (After Van Eck and Whiteside, 1958)

SOIL TYPE	READILY AVAILABLE WATER-SURFACE INCHES
Grayling sand	4.0
Kalkaska sand	5.7
Coloma loamy sand	9.6
Hillsdale sandy loam	10.5
Miami loam	8.9

This data illustrates that sandy soils with a good proportion of the finer sands may be better reservoirs of readily available water than the finer textured soils.

The influence of fine sands, particularly in depth, has widespread implications in the current appraisal of forest sites and most certainly in soil classification procedures designed for use by forest managers. Soils frequently lumped together based on surface horizons may be vastly different in their potential for forest growth. An example of the effective water supplying capacity of sandy soils for plantation red pine is shown by the growth of contiguous blocks of forty-four-year old red pine on Grayling sand and Rousseau fine sand on the Huron National Forest in Michigan. The distribution of sand fractions in these profiles is shown in Table 2.

Of primary interest are the differences between the amounts of fine and very fine sand in the substrata of these two soils. What these differences mean in terms of additional readily available water and growth is shown in Figure 1. Although both plantations have been affected by a long period of slow growth following establishment, the effect of 11 surface inches of additional storage capacity for available water in the substratum of the Rousseau soil has produced 1.57 feet of annual height growth after the establishment period and 41 feet at age 44 as compared with 0.81 feet of annual height growth after establishment and 26 feet at age 44 on the adjoining Grayling sand. This relationship of red pine growth to finer materials in subsoil layers is similar to the report of White and Wood (1958) on the growth of red pine plantations on coarse outwash sands (Hinckley series) on the Pack Forest in the upper Hudson Valley of New York. It also emphasizes the importance of soil classification in terms which reflect important differences in site for forest growth.

A further example of the value of correctly interpreting soil-vegetation relationships comes from the work of Dyrness and Youngburg (1958) on the immature pumice soils of central Oregon. On areas mapped as a single soil type (Lapine loamy coarse sand), in the absence of discernible differences in profile characteristics, four distinct understory vegetation types were recognized, each indicative of

Table 2: Mechanical analyses of Grayling sand and Rousseau fine sand (as percentages of material < 2 mm, oven-dry basis) from Van Eck and Whiteside, 1958.

GRAYLING SAND							
Horizon	Depth inches	Fraction					
		Fine gravel 2-1 mm	Coarse sand 1-.5 mm	Medium sand .5-.25 mm	Fine sand .25-.10 mm	Very fine sand .10-.05 mm	Silt + clay <.05 mm
A ₁	0-3	1.3	39.9	38.6	14.3	2.9	2.9
B ₂₁	3-6	1.7	48.6	36.2	10.9	1.2	1.3
B ₂₂	6-18	6.6	33.3	38.1	21.1	.5	.3
C ₁	18-30	2.6	63.8	26.5	6.7	.3	.1
C ₂	30-120	.5	34.8	51.8	12.1	.6	.1

ROUSSEAU FINE SAND							
A ₁ , A ₂	0-3	.2	6.8	31.3	50.1	10.2	1.4
B ₂₂	3-10	.2	6.5	29.0	50.9	10.5	2.9
B ₂	10-22	.2	6.3	29.9	52.6	9.6	1.3
C ₁	22-46	.0	1.3	22.0	67.0	8.8	1.0
C ₂	46-90	.0	.1	1.9	55.3	37.2	5.5
C ₃	90-150	.0	1.0	2.1	67.5	27.2	2.1

a completely different effective environment and accompanied by changes in amounts of advanced timber regeneration, timber stand density, supplies of forage available for livestock and other characteristics important in forest and range management. Figure 2 shows grown mature ponderosa pine with understory of bitterbrush and sparse advance reproduction on the Lapine soil. Total nitrogen in the pumice profile varies from 1500 to 1600 pounds per acre. In contrast, (Figure 3) a denser stand of mature ponderosa pine with abundant advance reproduction, and understory of snowbrush (*Ceanothus sp.*) manzanita and bitterbrush on the same soil mapping unit. The major site difference occurs here because nodules on the roots of the snowbrush fix atmospheric nitrogen. The total nitrogen in the pumice profile on this type varies from 2000 to 2100 pounds per acre.

ADJUSTING SPECIES SELECTION TO SITE POTENTIAL

There is no doubt that we can and should be doing a better job in getting the right species on the right site. At the moment we are faced with thousands of acres of pioneer species which will never produce more than pulpwood sizes on sites that could be growing sawlogs. This is a monument to the reforestation policy which was based mainly on "we planted what was available from the nursery."

We are fortunate to have in this country a few species, namely, white pine, loblolly pine, and Douglas fir, which have the real capability of exploiting the productivity of a site. In other words, they do not terminate their period of rapid growth about the time they are approaching sawlog size (ten to twelve inches). It is the species that continue to grow well after they have exceeded this diameter that can, with management, put "sawlog silviculture" in a favorable light.³ An example of the tremendous potential of one of these species, white pine, was reported by Yawney and Trimble (1958) who described a remarkable plantation on a favorable site in West Virginia which at twenty-five years of age had trees sixty-five to seventy feet tall and of sawtimber size.

If we are to meet the challenge of forest production, let us define the sites where these prime producers can exploit the site potential and let them go to work.

CAN WE INCREASE THE SUPPLY OF AVAILABLE WATER

It has been mentioned previously and reported elsewhere (White, 1958) that available water in the soil is the key to forest production and also to the evaluation of forest sites. In fact, most of our reasonably successful site classification systems are, in effect, delineating soil site characteristics which are directly related to the site's ability to hold and supply available water in sufficient quantities for growth.

Other than taking this factor into consideration when we classify sites, what can we do about it? Examples of successful attempts to alter the water regime are the large-scale forest drainage projects in the Scandinavian countries which may stimulate a renewal of similar projects in the Lake States region of this country. Figure 4 shows slow-growing Scotch pine with a growth rate of about 0.1 cords per acre per year on shallow peat over sandy loam with a high water table restricting root development and site productivity. Drainage ditches like the one shown in the figure, spaced about 80 meters apart lower the water table eight to twelve inches, and can boost stand production to 0.5 cords per acre per year.

Water conservation on well-drained soils has been investigated by Zahner,⁴ who measured the effect of removing portions of the stand and also ground cover vegetation on the available water supply remaining for the crop trees. Figure 5 shows the effect of thinning pulpwood-sized pine stands on soil moisture depletion trends for the first three years after treatment. Figure 6 shows the influence of killing hardwood overstory on the growth of underplanted pine and the marked difference in soil moisture in the upper six inches during the critical summer months during the two conditions as compared with open bare ground planting. Effects such as these can be achieved with the proper use of herbicides (Arend and Roe, 1961).

Speaking of herbicides, a recent development of a soil applied selective material—simazine⁵ has made possible a real breakthrough in the control of weed competi-

³ S. O. Heiberg, Personal communication.

⁴ Personal communication.

⁵ 2-chloro-4, 6-bis (ethylamino)-s-triazine

tion in coniferous plantations. This material which remains in the upper few inches of soil is assimilated almost entirely through the root system and inhibits the formation of the chlorophyll molecule, resulting in the death of most germinating weed seeds. Fortunately most conifers and many hardwoods exhibit a high degree of resistance to the effects of this chemical at levels lethal to germinating grasses and forbs. The mechanism of resistance by tree species is not fully understood and may be related to the mycorrhizal relationship. Used alone or in combination with other herbicides, simazine can be used in many types of forest plantings to produce increased survival and growth with resulting economic advantages (White, 1960). Figure 7 shows the effective weed control achieved at the end of the first growing season in a white spruce plantation by the application of four pounds per acre of active simazine applied in a two-foot-wide band immediately following furrow planting.

In another study just off the press, Walker, Green, and Daniels (1961) showed the effects of raising and lowering the water table on the survival and growth of slash and loblolly pine seedlings. These tests clearly indicated the superior ability of loblolly pine to withstand periods of inundation and serve as a guide in the establishment of pine plantations on waterlogged soils and soils subject to periodic inundation.

Stone et al. (1958) defined the important relationship between the productivity of red pine and soil drainage classes from poor to excessive. The strong correlation between site index and soil drainage class in New York plantations is illustrated in Figure 8. This clear-cut delineation of limiting conditions of soil drainage for red pine is a very helpful indicator of potential site hazard for forest managers. What happens to the root system of normally deep-rooted red pine on poorly drained soils is shown in Figure 9. It should be pointed out, however, that these findings which are most strongly expressed on medium-textured soils do not necessarily indicate as severe a hazard in other areas within the natural range of red pine. For example in the Lake States region generally coarser soil materials somewhat modify the effect of impeded drainage and shorten the period of influence during any particular growing season.

Although we can eliminate a certain amount of excessive water use by judicious elimination of parts of stands and competing weed and understory vegetation, the application of additional increments of water through irrigation (Zahner, 1958b; Stout, 1959) seems beyond the capabilities of the forest manager. This does not preclude, of course, the application of irrigation water for physiological studies, growth of seed orchards, and specialized plantings, like windbreaks. Then there is always the possibility that we may make rapid strides in the planetary engineering mentioned earlier when irrigating forests may be as commonplace as irrigating orchard crops.

One attempt to improve the water relations of coarse sandy soils now under investigation at the Michigan Agricultural Experiment Station is the placement of thin bands of bentonite clay ($1/16$ inch) or layers of thin (2 mil) polyethylene plastic about twenty-two inches below the surface. This technique has the effect

of limiting excessive water losses in soils lacking natural development of finer-textured materials in the subsoil. It may be an effective treatment in forest nursery practice or in such specialized areas as highway borrow pit plantings. Any influence of this technique on forest production in the future is still in the realm of dreaming. Details of the plastic film-laying machinery are shown in Figure 10.

ADJUSTMENT OF SOIL FERTILITY

The post-war forestry literature has been characterized by a large number of papers related to the problems of forest fertilization as well as to the more basic studies on tree nutrition (White and Leaf, 1957; Leyton, 1958; Stoekeler and Arneman, 1960; and others). The use of soil amendments to stimulate forest growth has achieved outstanding success on areas of nutrient deficient soils such as the response of Scotch pine to phosphorus on a Scottish moor shown in Figure 11 and the well known dramatic response of Monterey pine to small additions of zinc in New Zealand. In these situations the use of soil amendments is an actual requirement for establishment and maintenance of forest trees. In Germany Brüning (1959) has reported on the successful use of potassium and magnesium soil amendments for successful establishment and growth of Scotch pine and black locust. In America many workers have shown significant increase in growth over short periods (Gessel and Shareff, 1957; Maki, 1958; and others). The localized potash deficient soils in the northeast have shown long term effects to single potash applications with red pine, white pine, Norway spruce, and white spruce (Heiberg and White, 1951; LaFond, 1958). By and large the practical use of soil amendments in American forestry is still a technique for special situations such as plantation establishment (in conjunction with weed control), severely depleted soils, shelterbelts, seed orchards, dune sands, eroded sites, highway borrow pits, and spoil banks. In these situations using pelletized materials or slowly available sources, which can provide supplemental nutrition over a period of years from a single application, we can expect to achieve substantial benefits from fertilization.

One exception to the limited use of fertilizer is the Christmas tree industry where the large, short rotation yields can show high economic returns from modest investments in fertilizer. In fact, this practice is generally recommended for the more demanding species such as spruce, Douglas fir, and white pine intended for Christmas trees. An example of the highly successful use of fertilizer to bring a checked fourteen-year old white spruce plantation in Wisconsin, originally intended for pulpwood but "off site" on a coarse outwash sand, to profitable utilization for Christmas trees is shown in Figure 12. A company policy decision to liquidate this stand and convert to a less demanding species prompted an attempt to recoup some loss from the original investment. Portions of the stand were treated in the spring of 1960 with from one-half to two pounds per tree of a complete (12-12-12) fertilizer, distributing the material under the tree crowns. Foliage and growth response in the subsequent growing season were dramatic and resulted in such improvement in growth and quality that a contract

was completed to liquidate eight acres of the plantation for Christmas trees over a three year period at a substantial profit. In this case, the cost of labor, material and fertilizer application amounted to 6.5 cents per tree and subsequent shearing and shaping costs of 8 cents per tree.

In considering the ways in which manipulating the soil fertility may increase forest production we cannot overlook the forest nursery and the impact of the nursery environment on the plantations that will be produced from the nursery stock. Much of the credit for the development of rational nursery soil fertility management programs in the United States must go to Wilde (1958) who pioneered the application of sound soil science principles in forestry.

Some years ago Wakeley (1948) stressed the importance of "physiological grades" of nursery stock. His work followed by that of May (1958) and Switzer⁶ clearly shows that the balance of fertility in the nursery environment can affect plantation growth for some years after establishment. An example from the Mississippi Agricultural Experiment Station shows that nitrogen content of loblolly pine raised at various levels in the nursery is closely correlated with growth for at least six years after planting. Figure 13 shows different physiological grades of loblolly pine growing in research plots in Mississippi.

SPECIAL PROBLEM AREAS

As a result of strip mining activities in various parts of the country, especially in the central states and in Minnesota, rather large areas of formerly productive forest land have been at least temporarily destroyed. Although the removal of these lands from production has not seriously affected the supply of forest or agricultural products, their successful rehabilitation is, nevertheless, a challenge for the future and certainly their rehabilitation conforms with the multiple use concept of modern American forestry. An example of successful rehabilitation of coal spoil banks with good forest growth of red and white pine is shown in Figure 14. It should be explained that the plantation shown was established before regulations required grading and treatment of spoil banks. Modern techniques, including fertilization, will achieve greater productivity over a large percentage of similar areas, some of which are still currently in a waste condition and an eyesore.

SUMMARY

We have in this brief period attempted to look into the future and evaluate present practices in manipulating or classifying soils to achieve greater productivity on forest lands.

Presently the most progress is being made in more meaningful methods of soil classification and mapping as guides to plantation establishment and forest management.

Methods for making the most use of available water or providing more water for crop trees by the elimination of unwanted vegetation have been reviewed.

⁶ Unpublished data.

Benefits to be achieved from the removal of excess water by drainage have also been illustrated.

Attempts to adjust productivity by the use of soil amendments have been shown and the areas most suitable for successful use of this technique have been indicated.

The increased production that may be achieved from a better understanding of soils and judicious manipulation of soil properties have been demonstrated by forest soils specialists. It is up to the silviculturist and the forest manager to decide where he can economically make use of the techniques successfully demonstrated by research.

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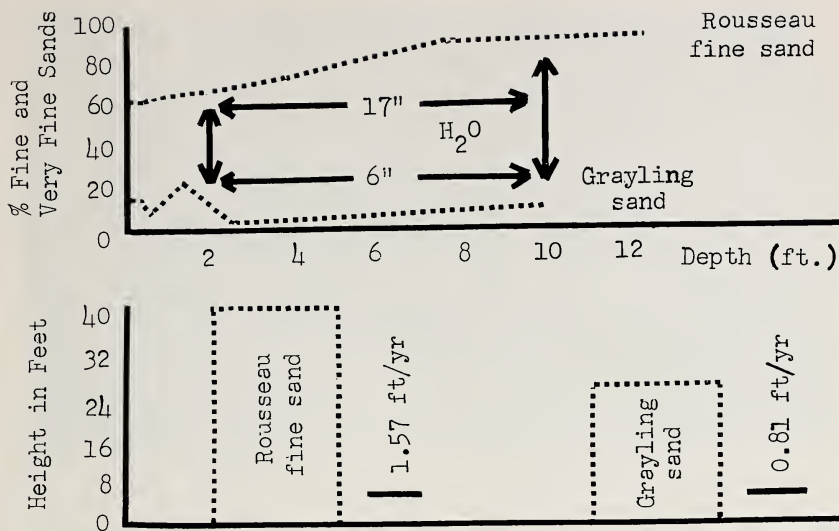


FIG. 1.—Influence of fine sand fractions in C horizon on relative available water storage and growth of red pine on Rousseau and Grayling soils. Huron National Forest, Michigan. (After Van Eck and Whiteside, 1958.)



FIG. 2.—Open grown mature stand of ponderosa pine with understory of bitterbrush and sparse advanced reproduction on Lapine loamy coarse sand. Total nitrogen in pumice profile varies from 1500-1600 lbs/acre. (Dyrness and Youngberg, 1958.)



FIG. 3.—Dense stand of mature ponderosa pine with abundant advance reproduction and understory of nitrogen fixing snowbrush (*Ceanothus* sp.) on Lapine loamy coarse sand. Total nitrogen in pumice profile varies from 2000 to 2100 lbs/acre. (Dyrness and Youngberg, 1958.)



FIG. 4.—Drainage of shallow peat over sandy loam in Finland to increase growth of Scotch pine. Ditches spaced at 80 meters drop water table 8-12 inches and result in annual production increase from 0.1 to 0.5 cords per acre. (Courtesy, J. H. Stoeckeler, U.S. Forest Service.)

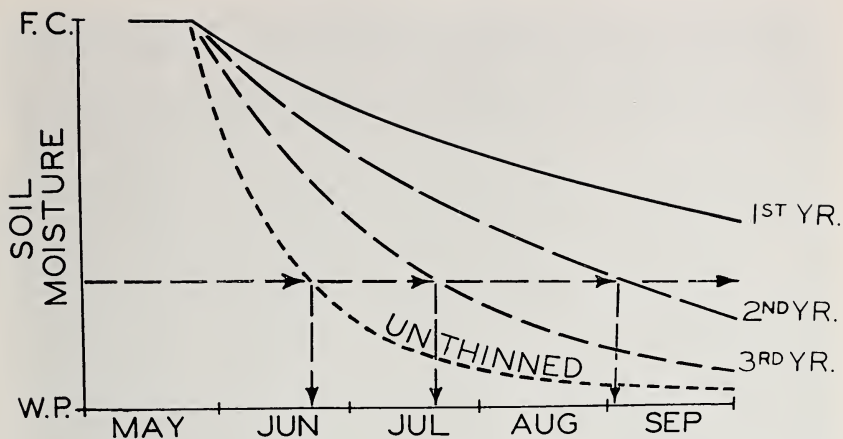


Fig. 5.—Effect of thinning young stands on soil moisture depletion during growth season. F.C.—field capacity, W.P.—wilting point. (Courtesy, R. Zahner, University of Michigan.)

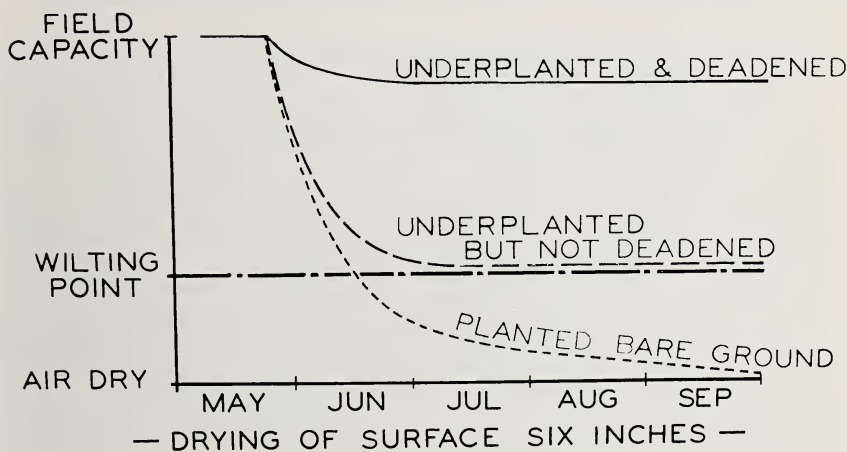


Fig. 6.—Effect of deadening overstory on growing season available water for underplanted pine. (Courtesy, R. Zahner, University of Michigan.)



FIG. 7.—Control of weeds in white spruce plantation with 4 lbs/acre of active simazine applied in two-foot band over furrow after planting. Photo: end of first growing season (White, 1960).

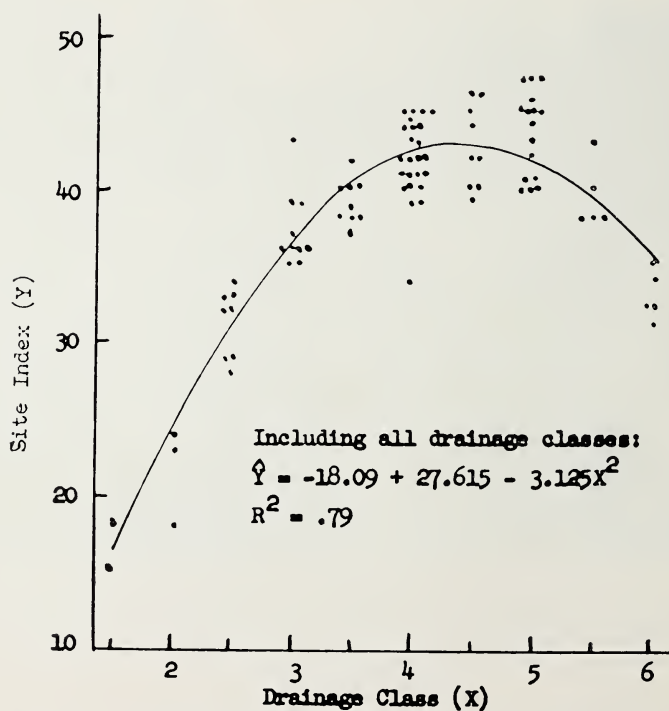


FIG. 8.—Relationship of site index of red pine to soil drainage in New York (Stone, et al., 1958).



FIG. 9.—Root of red pine growing on poorly drained soil. Note truncated root system (Stone, et al., 1958).

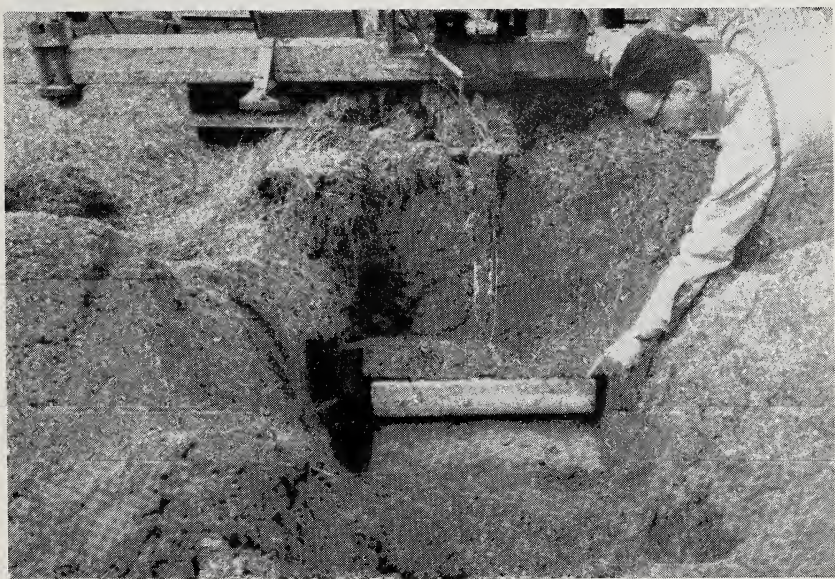


FIG. 10.—Placement of thin plastic film in coarse sandy soil creates artificial barrier against excessive loss of percolating water. Polyethylene film (2 mil) increases storage of readily available water in upper 22 inches of soil. Trench is excavated in photo to show detail. (Courtesy, A. E. Erickson, Michigan State University.)



FIG. 11.—Response of Scotch pine on Lon Mar, Scotland, to applications of phosphorus as basic slag. Left, control; right, basic slag, 5 cwt/acre in 1928 and 1930. Planted 1926, photo 1958. (Courtesy, L. Leyton, Oxford University.)



FIG. 12a and b—Response of 14-year-old white spruce on coarse sand to heavy application of complete fertilizer. 12a—untreated. 12b—treated spring 1960 with 1 lb. 12-12-12 per tree broadcast under crown. Photos August, 1960. (Rhineland Paper Company, Wisconsin.)



FIG. 13.—Loblolly pine seedlings raised under controlled levels of fertility for field tests of physiological grade. (Courtesy, G. Switzer, Mississippi State University.)



FIG. 14.—Rehabilitation of spoil banks left after strip mining by red and white pine.
(Courtesy, O. D. Diller, Ohio Agricultural Experiment Station.)

Management Considerations

THEODORE W. EARLE
Vice President

Continental Can Company, Inc.

Our country's strength and world position is based on an abundant supply of natural resources. Without this supply of natural wealth, our past technological advances would not have been possible. Of our many resources, only timber can be replenished in a reasonably short period. It may take centuries to re-establish a water source, cons for oil and coal. As our un-renewable resources are depleted, we are going to depend more and more on timber for the basic raw materials required to support our way of life. Under present economic conditions, there are 529,000,000 acres of land capable of growing commercial timber crops in the United States—including Hawaii and Alaska. The remaining 255,000,000 acres of forest land are in dedicated wilderness areas, in inaccessible locations, or land that will not support commercial timber species.

This available acreage is now providing the more than 5,000 wood products we use in our every day life. Will it be able to continue to meet the demand of a growing nation and world? The Forest Service, in its Timber Resources Review, predicts that between now and 2000 A.D. more than 123 million acres could be diverted to agricultural use, rights of way, urban sprawl, and others. This represents a loss of 25 per cent of our timber growing capacity.

What about consumption during this same period? During the past twenty years, our per capita use of lumber has remained constant. At the same time, our per capita consumption of paper and paperboard has nearly doubled. Let us assume the current per capita consumption levels remain constant for the next forty years. This is certainly conservative in light of the expanding use of plywood, poles, piling, fiber and chemical products derived from wood. Our exploding population alone, from 180 million now, to 300 million at the turn of the century, will increase the demand for forest products to 170 per cent of its present level.

In light of this 25 per cent reduction in production potential, and 170 per cent increase in demand, the need for intensified forest management on the remaining acreage becomes obvious. Before we develop this discussion further, it behooves each of us to have the same definition of Forest Management in mind. Just what is forest management? The Society of American Foresters defines it as, "The application of business methods and technical forestry to the operation of the forest property." A forest ownership is an investment like any other. It is paramount that current or periodic income will exceed expenses, and that the ownership objectives of the investor be accomplished.

Profit potential—the degree to which income will exceed expenses, and the techniques suitable for use in producing this profit, vary widely with the con-

dition of the land, management objectives, and sizes of the ownership. The forest industries, on a nation-wide basis, are making great strides in developing "mass production" techniques for managing forest land. These methods are economically feasible only because of the rapidly increasing demand for forest products and the resulting urgency to attain full stocking as fast as possible. In many cases the large capital outlay required to carry out these programs prohibits their use on small forest ownerships. The older, simpler silvicultural systems must be used. Before any system can be successfully applied, however, the small land owner must be convinced that there are financial benefits to be derived from good forest management. Herein lies a great challenge to the entire forestry profession. If we are going to meet the production demands of the future, every acre of forest land must be in production, not only the large industrial holdings and the Federal ownerships.

The Forest Industry has recognized this problem. Through cooperative efforts such as the American Forest Products Industries Tree Farm program, the Southern Pulpwood Conservation Association, Forest Farmers Association, and other similar organizations, progress is being made "selling" the public good forest management. In addition, the individual wood using companies, through on-the-ground advice and assistance, are demonstrating, to the small land owners, that forest land can be profitable. We still have a long way to go, however.

The rest of my remarks will be confined to industrial forest management—here, where motivation and capital are available, is one of the areas in which the challenge to forest managers can, and is, being met.

For a minute, let us evaluate the Forest Industries present position in forest management. A forest ownership evolves through a series of stages in its progress toward full forest production and sustained yield on every acre. These might be listed as:

(1) The acquisition phase—cruising, purchasing, surveying, and mapping the land.

(2) The protection phase—the institution of a fire protection system and the development of good public relations, so that the public understands and respects the objectives of forest management.

(3) The organization phase—where the property is organized into administration and management units.

(4) The development and improvement phase—that period of time during which open fields and unstocked lands are planted, and basic road and other improvement construction takes place.

(5) The production and regulation phase—when overmature and otherwise undesirable stands are cut, and overall efforts are directed toward improving timber quality, quantity, and age class distribution.

(6) The continuous yield phase—during which the administrative areas are organized into production units, and detailed plans of cutting and treatment are prepared.

(7) The final stage—maximum sustained yield.

Over much of the South the forest industries have passed through the acquisition, protection, organization, and development phases and are now at the production and regulation phase. It is at this point, and in the ensuing stages, that the greatest need for advanced technology, both business and scientific, is required. Because I am most familiar with my company's operation, and also because it provides an outstanding example of rapid development—of course, I might be a little prejudiced—my remarks for the next several minutes will be confined to Continental Can Company's Woodlands Division.

We own, or execute direct management control over, slightly more than 1,300,000 acres of forest land in seven (7) Southern States. These range from Virginia along the coast through North Carolina, South Carolina, Georgia, Florida, and across the Mississippi in Louisiana and Arkansas. This land was placed under management as soon as we purchased it. It is divided into four (4) separate 250,000 to 300,000 acre districts, each of which supports a Kraft or bleackraft paper mill. Each district is under the supervision of a forester, whose title is District Woodlands Manager. The district is divided into administrative areas, ranging in size from 25,000 to 65,000 acres, for ease of management and control. Each area has a Technical Forester in charge, who reports directly to the District Manager. This Area Forester may have one or two assistants, depending on the size of the area and its work load. The District Manager, in addition to these Area Foresters, has men of proven ability on a staff level who provide assistance and advice in: Forest Management, Engineering and Development, Wood Procurement, and Accounting.

The Area Foresters and their assistants live as close to the center of their areas as is practical. These men are completely responsible for all of the operations that take place in their areas. This decentralized operation has many advantages. Being responsible for both planning and executing the work, each area man is actively interested in improving techniques and operating methods. Rather than merely carrying out rigid procedures, each man can, and does, have an opportunity to bring his own creative ability to bear on the various problems. A second factor is that the men, living in the local areas, become associated with, and a part of, the community in which our land lies. This helps to establish a closer relationship between the company and local people. Our status changes from "those pulpwood people" into an identified member of the local society. This acceptance creates the atmosphere necessary to carry out an intensive forest management operation.

Our paper mills are predominantly pine consumers at the present time. Because of this, our silviculture is directed toward propagating relatively intolerant pine species in managed even-aged pure stands. In the early management stages, activities such as the complete exclusion of fire, and the partial cutting of pine stands, favored the development of hardwood species on many sites. The urgency of building an organization, acquiring land, and protecting it from destructive wild fires, made the application of systematic studies and management plans impractical. Only after these early growing pains were passed, and the production and

regulation phase was reached, could we begin to truly apply intensive forest management over our entire forest holdings. We can now organize our activities so that the management objectives are approached in an orderly and systematic manner.

The first step in this regulatory process is to subdivide each administrative area into easily defined management units of approximately 1,000 acres each. These units, or compartments, form the basic planning, execution and record keeping entity.

The compartments are then combined into five cutting cycle groups. Each year, one of these groups, of from four to twelve compartments, is examined and treated, so that every acre is gone over and given any attention needed once every five years. When this framework is constructed, the efforts of our personnel are no longer "shotgunned" over the entire holdings, but are concentrated on a definite one-fifth of the area each year.

In actual practice, our procedure is to examine and classify, according to a series of coded forest conditions, one of these cutting groups each year. These codes describe the forest type, soil site class, topography, age, size, and stocking of each stand within the group. In addition, the examining forester includes a coded silvicultural recommendation.

The summary of these recommendations, which include an estimated volume to be cut from each stand, form the basis for next year's operations. Following the examination of next year's cutting group, and within the framework of a tentative cutting budget developed at district level, the Area Forester prepares a detailed work plan for his area. These plans are submitted to the district staffs, where they are weighed in relation to the plans and recommendations from other areas. The final district work plan is then submitted to the division office in the form of an annual budget where it is again evaluated and finally approved or modified.

The tentative budget, developed for the Area Forester's guidance, is based on information gained from our continuous forest inventory. This continuous forest inventory is based on the re-measurement, at five year intervals, of randomly located, permanent, one-fifth acre plots. The statistical error incurred when applying the inventory data at district level is insignificant. This data serves, not only as the basis for tentative annual plans for each area, but also as a basis for a Five Year District Management Plan and as a source of information for longer projections which are sometimes required by our Executive Offices in New York.

Let's go back now and examine this process in a little more detail. Our objective is to attain full pine stocking and maximum production as rapidly and economically as possible, while at the same time, maintaining a more or less uniform yield of forest products and dollars. This yield will gradually increase as stocking improves. When the forester goes into the field to examine the forest stands, he has a large number of factors to consider. Is the stand currently yielding a satisfactory rate of return? If it is, can it be increased by some silvicultural treatment? If it is not, should it be cut immediately, or are there other stands up for treat-

ment which should carry a higher priority? If the stand is to be cut, what regeneration system should be used? As demonstrated by Don White's paper, soil site capacity plays an important part in this consideration. Over most of our districts, we are clear cutting and regenerating by planting, following some form of preliminary site treatment.

Today's forester has a large number of mechanical and chemical tools which can be used individually, or in combination, to carry out this regeneration. The proper treatment has tremendous effect on both current and future operating costs and production. In some cases, a treatment such as piling the cull hardwoods with a tractor, and harrowing the site two times, is cheaper in the long run than a more moderate initial treatment, which allows excessive hardwood sprout development or poor planting survival. All of our planting stock comes from controlled seed sources. The cost of maintaining a partially stocked stand in light of today's high fixed overhead, such as taxes, employee fringe benefits, etc., is prohibitive. Every acre must be made to produce at as near capacity as present technology and economics will allow.

In our effort to increase this per-acre production, a series of independent and cooperative research programs are in progress. I would like to mention two of these because of their great importance. The first of these is the "Tree Improvement Program." Here, we are attempting, through the normal techniques of plant breeding, to develop a strain of pine trees which demonstrates to a superior degree the physiological characteristics deemed most important by the project participants. We hope to come up with a plant characterized by high wood specific gravity, straightness, small branches, rapid growth, and resistance to disease. The approach to this program is two pronged:

(1) For the immediate future—develop a phenotypically superior source of seed through natural seed production areas. In this operation high quality stands are very selectively cut so that only 7–10 of the best trees are left per acre. These are fertilized, sprayed for insect and cone rust control, and otherwise carefully treated. They serve as the seed source for our present nursery plantings.

(2) For the long range—to develop a genetically superior strain of trees through plant breeding. We are carefully selecting and testing "superior trees"—those natural specimens which demonstrate the desired characteristics. These serve as parents and provide scions which are grafted on rootstocks in Seed Orchards. As these orchard trees begin to bear seed, progeny testing will be done, and those individuals which do not actually demonstrate the desired superior qualities will be eliminated.

The second study I would like to mention is in the field of forest pathology. One of the greatest single problems in the management of pure pine stands is disease. These large, even-aged stands set the stage for disease infestations of epidemic proportions. Even endemic or normal levels of such infections as *Cronartium fusiform*, a rust which produces canker in pine, and *Fomes annosus*, a root-rot fungus, are problems of considerable magnitude. In conjunction with the Pabst Brewing Company, we are engaged, in the South, in an evaluation of

two antibiotics similar to penicillin, which have indicated an effectiveness in the control of forest diseases, particularly white pine blister rust in the West. If these preliminary indications bear up under study in the South, and the antibiotics can be economically used, we will have made a tremendous stride in forest management. I seem to have strayed from the original line of thought and had better get back to it.

After the Area Forester has decided what treatments will be required in each compartment, he is in a position to determine the type of equipment and hours required to treat the land, the personnel requirements for planting, timber stand improvement, access road construction, and the various other phases of the operation. Once this information is in the hands of the District Manager and his staff, they can intelligently determine immediate capital requirements for equipment, decide what operating funds will be needed, and ascertain whether the plans are compatible with the company's operating and fiscal policies. They also evaluate their effect on taxes, income, and the local communities.

One of the factors often omitted in a discussion of forest management is the interrelation of these forest management developments with the operations of the crews actually cutting and hauling the wood. No matter how good a management technique may look from a forester's standpoint, if it adversely affects logging, either it, or the logging methods, must be revised. It is in this particular segment of forest management that we in the South, and actually in the nation as a whole, are woefully weak. If I were to suggest that a farmer harvest and thrash a field of hybrid wheat, using sickle and flails, he would only laugh; and yet in this day of electronic brains and rockets, our logging crews are still using procedures only slightly improved from those employed forty years ago. In the face of rising labor and transportation costs, we must develop high-speed mechanized methods for logging and wood handling or reconcile ourselves to steadily increasing raw material prices. Although some improvements have been made, and a few studies are in progress, there is still a huge void to be filled.

We have touched briefly on a few of the problems and practices of today's forest managers and indicated that the future problems will become, if anything, more complex. How will this affect future personnel requirements?

There will definitely be a need for trained forestry graduates throughout our economy, if the Herculean task of meeting the future demand for forest products is to be accomplished. Within the forest industries, specifically, we will need men at all levels—field, research, supervisory, and administrative. The technical requirements imposed on these men will steadily increase, but at a more rapid rate and of more urgent concern, will be the demands on common sense, knowledge of people and business acumen.

Our educational institutions are faced with a real dilemma as forestry becomes a bigger and bigger business, and foresters are expected, and required, to assume higher positions in the organizations for which they work. These positions require a broader outlook than can be attained through a strictly technical education. Time must be allotted to the Arts and Humanities, if the wide interests of a true

leader are to be developed; and yet the colleges will be pressed to include new technical courses to keep up with rapid technological advances. In this vein, I might say that it is rare, indeed, for a man to fail because of technical inability once he has achieved a diploma from an accredited school. More likely to spell disaster is the lack of initiative, human insight, active curiosity, or the ability to get along with people. Some of these are not gifts, but capabilities acquired through hard work, study, and guidance. It is essential that our schools provide, not only modern technical curriculums, but also the atmosphere and courses required to develop these characteristics in their graduates.

Never should the liberal arts phase of the education process be sacrificed to the technical. One of the greatest weaknesses in the forestry profession, has been the foresters' inability to meet with, and sell themselves to, men with a variety of backgrounds. They have allowed themselves to be catalogued as "woodsmen," "nice fellow," but not for use in the front office. Only with capable leaders can the forestry profession meet the challenges of our free enterprise system.

A healthy, vital forest economy, which we will need to meet world competition, will require both intensive forest management and capable leadership. We all know that today, a very large percentage of the world's forest resources fall under the control of world communism. Russia's accessible forest land includes 2.5 billion acres, containing 65 per cent of the world's softwood timber. By applying intensive research and development, they are said to have gained one of the most highly mechanized and efficient logging operations in the world. In 1958 their lumber production exceeded that of the United States.

From recent reports, we know that Red China has planted 50 million acres to trees and bamboo, and have a goal of 165 million acres by 1965. In this economic war, the responsibility of handling our forest resources no longer carries domestic connotations only, but has direct effect on our national security. Great strides have been made in forest management during the past decade. In light of the anticipated growth in population and demand for forest products during the "soaring sixties" and after, our efforts must be almost doubled unless we are willing to face rationing of our morning newspaper, cartons for shipments, and wood for new homes.

I am confident that the need *is* recognized, that our schools and universities *can* provide the trained personnel, and that our free enterprise system *will* rise to meet this challenge.



PART FIVE

CHALLENGES IN NEW WOOD USES



Challenges in the Use of Wood

HOWARD W. MORGAN
Vice President
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Challenge is an exciting word. It brings to one's mind the idea of great things to be done, hard battles to be won, obstacles to be overcome and new things to be learned. The word looks to the future and is most appropriate in thinking of how we will profitably use the tremendous quantities of wood being grown today in America's forests and on her tree farms, and make no mistake the growing of wood as a crop is well established as major business. I for one have no fears that this nation will find itself with a serious wood shortage. The only requisites are adequate future planning to be sure that sufficient areas of timber are grown, and a public understanding of the principles of tree farming that provides a tax policy conducive to making provision for the future timber supply. Heavy taxes during the growing cycles discourage the holding of adequate reserves of growing stock, whereas taxes geared to full growing cycle encourage wise and orderly forestry policies.

Trees are a crop taking from 25 to 100 years to mature, and an industry dependent on wood as a raw material must look far ahead to its future supplies. Fortunately, most wood-using industries and large numbers of individuals have seen this and, believing in the future, have invested the money and efforts to establish forests for future use. The greatest stimulus to this is the profitable market that has been available, and as the use of wood grows so will the interest in growing wood expand. I take this liberty of straying into the field of forest management because uses are so dependent upon well-managed wood supplies, and forest management is so dependent upon more and more profitable ways of using wood.

The broad challenge is to use wood to serve the common good through new and better products and lower cost commodities that can contribute to the needs and well being of the people. This is a challenge of great import to our nation, for this country is blessed with large land areas well suited for growing trees, though they are not suited or are not needed for growing other crops. If the crops of trees that these areas can grow can be used to make needed products at a profit, these land areas will add to the wealth and well being of the nation. On the other hand, if there is not a profitable use for the trees, interest in growing trees will wane. Don't misunderstand me. I am sure we will always have a large use for wood, but the amount can vary widely, depending upon what we do about finding the uses and taking advantage of them. The more uses that are developed, the more trees that will be grown and the more acres of forest land put to profitable use. In the end, profit or the hope of it is the only motive that

will bring the operations of tree farming and the wood-using industries into full effectiveness. Profit, however, is a small part of the contribution to the nation. A far greater contribution is the opportunity that such integrated forest management and manufacturing enterprises offer for satisfying and remunerative careers for many thousands of people. We all know that opportunity for gainful employment is the basis of a sound and growing economy. In this country the best available figures indicate a total employment in the forest industries of 1,200,000 people, or 7.5 per cent of the total employment in manufacturing. The Bureau of Labor Statistics' figures indicate that the combined lumber and paper industries rank sixth in the number of people employed in the list of twenty-one industry classifications.

How is the broad challenge of wood use to be met? How can we grasp the opportunities that exist? All successful businesses involve three main lines of endeavor: product development, which frequently involves research; manufacturing and marketing. The last is the most important in most cases.

Marketing as used here includes not only selling and distribution, but more importantly, study of the needs of the consuming public. The objective of needs to be filled lend direction to the development and perfection of new products. Many great achievements have been accomplished by people who saw important human needs and then went to work to fill them.

I believe it is correct to say that the great success of Henry Ford was not due to his engineering and manufacturing skill, great as that was, but rather to his conviction that the American public needed a good, serviceable car that sold for less than \$500. That is what he set out to do, and did, with his famous Model T. He recognized a market and he organized an industry to satisfy that market, at a price it was willing to pay. His success was one of the greatest in American industry.

Our challenges today are not much different. When we can find the important needs of our times and can meet them with products at an acceptable price, we have success.

Price is an ever important factor and one that frequently plagues the wood-using industries because of the competition of many other materials. The future size of these forest industries depends to a large degree upon providing our products at equal or lower cost than the competing products. Cost is the major challenge of manufacturing, and these industries are fully aware of it. No factor receives greater attention in the operation of the modern wood-using plants.

If progress in manufacturing methods is not continually made, increasing wages, taxes, and other costs could price our products out of the market. Some important accomplishments have been made. Today lumber prices are no higher than they were five years ago. The most important cost reductions in the postwar years have been achieved through integrated manufacture of lumber, wood pulp, and other products. Sawmill waste had been used in small quantities for the production of unbleached paper and paperboard for many years in the Northwest, but it was not until the late 1930's that bleaching methods were developed which

allowed the use of Douglas-fir for bleached pulps of good quality. World War II sidetracked this development; but following this, the industry quickly put this development to work to meet the rapidly increasing demand. I am sure that in the Pacific Northwest today more chemical wood pulp is made from logging and sawmill wastes than from whole logs or cordwood. This integration applies to the small sawmill as well as the large, for barking and chipping equipment is added to a small mill and the resulting chips sold to a pulp mill, and most of the smaller sawmills in Washington and Oregon are so equipped. The importance of this integration can be illustrated by the fact that the return for the chips is often as large or larger than the profit of the whole operation. More of this type of development is badly needed to meet the economic conditions that wood-using industries face. More profitable uses for sawdust and bark, which are now largely used only for fuel, and the discovery of more profitable conversion of used pulp mill cooking liquor could give a real lift to the economic improvement of these industries.

Wood, which is our most adaptable building material, has for years faced the active competition of many other materials. Metals, concrete, glass, and a wide variety of compositions have been aggressively marketed and have replaced wood to a considerable extent for some building uses. As an example, composition shingles have replaced a majority of the wood shingles. Metals have made sizable inroads in the use of wood for window and door frames. The *Wall Street Journal* just three weeks ago published a front-page feature article, headlined "Materials Melee—New Steel, Concrete, Glass Products Step Up Construction Rivalry—Aluminum Firms Seek More Home-Siding Sales; Plastic Floors Battle Hardwood." Cost, and in some cases, performance, has been a factor causing some of these changes. Not to be ignored is the novelty and flexibility that new materials have given architects in the development of new concepts of design and construction. While lumber has lost in some items of building, it has maintained a pre-eminent position almost undisputed in framing for home construction and many other lumber uses have been taken over by plywood and other wood products.

The application of research to the use of wood products in building has not had the attention it deserves. This type of study, coupled with experimental design, will give great aid to wood in meeting the needs of the times. Such research would involve engineering and architectural studies. The Douglas Fir Plywood Association has contributed much to that industry through this type of approach. The lumber industry now shows interest in the same type of approach. Organizations such as the Building Research Institute, the National Association of Home Builders, the University of Illinois Small Homes Council, the Forest Products Research Laboratory in Madison, Wisconsin, are all working in this field. We at Weyerhaeuser have a new research facility in Seattle, Washington, which directs its efforts to make more use of forest-derived products and materials in building and construction.

Architecture like other arts is ever seeking something new, a better functional design, a more attractive form, or sometimes just something different.

The lumber industry has been slow to follow architectural trends, and our greatest challenge in marketing wood products to the building industry lies in adapting wood to the designs of today and of tomorrow. Fortunately, much has been done in recent years and is being done now. Plywood's adaptability is continually expanding its use. Various types of hardboard and particle board find increased application. Engineering developments such as prefabricated roof trusses and wall sections are introducing both labor and material savings. The techniques of laminating wood have been greatly improved in recent years. Laminated beams and arches of many sizes and shapes are giving wood new dimension, utility, and beauty . . . from barns and warehouse to homes, churches, and schools. Panel laminates from structural plywood to beautiful hardwood-faced interior panelling are forms of wood already well established and continuing to expand in use. Large laminated beams and prefabricated roof trusses are produced at a cost which competes with steel for the framing of large buildings and give an appearance that is vastly superior. Short pieces of narrow boards are now glued with waterproof adhesives to make panels of good appearance and great utility. The factory prefabrication of house-building units is providing a real advance in lowering the cost of building. Like Henry Ford and his automobile, the success of the large home-building corporations has been due to the same ability to sense the needs of the market and devise methods of producing and financing a home at a price that a large number of users will pay. It can be predicted that factory efficiency can be applied to the structural work for house designs using wood at substantial savings, and that the more expensive on-site work can be limited to assembling and applying the exterior and interior finishes which can be varied to suit the taste of the buyer, resulting in lower cost homes.

Wood in the form of framing lumber is the ideal material from which to build the units of construction. Plywood, hardboard, particle board, wood-fiber insulating, all can find wide application in completing the structure. There is a real challenge in adapting wood products now available to architectural ideas of the age and in bringing to the attention of the architectural and building people the new things in wood that allow the development of new forms and designs in architecture. The use of lumber probably has suffered, because many architects and builders think of it only in traditional uses—as beams, framing and boards. If the present advanced architectural thinking can again be focused on wood and the adaptable forms in which it can now be manufactured, wood products will enjoy an even larger share of the construction market.

Since research is mentioned throughout this talk, it may be well to make some specific comments regarding it at this point. We cannot talk about future progress in the industry and new uses for wood without thinking of research and its place in these matters. Naturally, a businessman hesitates to speak too boldly on research in the university atmosphere, which is so saturated with advanced thinking in these endeavors; nevertheless, it is a subject that should be talked about and one on which many businessmen could profit by a more realistic understanding of its possibilities and limitations. Too often we are inclined

to feel that all that is necessary is to build a laboratory, hire the scientists, give them a budget, and then the highly profitable discoveries will flow in. This result does not happen unless the research activity is directed to fertile fields of investigations, and it takes sound management planning to channel the research activity toward markets and products that are of commercial value, and to see that the results of the research are carried through to successful commercialization. Management has a major responsibility in planning research and in using the results of it.

The word research has become somewhat abused, since it has become so popular, and a definitive meaning is important. By research I mean a systematic, intensive study directed toward fuller scientific knowledge of a subject. It includes both fundamental research and applied research, which differ depending upon their objectives.

Both are important and the first often more important than the latter, for it develops the knowledge on which the latter draws. Any company which has a sizable research program should allocate some of its most able scientists to fundamental work with the instruction that they find out more about a given field without an objective of developing a specific product to be sold.

Wood presents some real unsolved challenges in research; problems that have been recognized for many years but still are not completely solved. Take the case of lignin, a fraction of wood that is removed in chemical pulping and used for fuel or, in many cases, discarded. The used cooking liquors from chemical pulping carry as much as twelve million tons a year of this material. Many researchers for a long time have directed their efforts towards this challenge—fundamental researchers toward learning what lignin is, and applied researchers toward making useful products. Many uses have been found but, while very interesting, do not begin to have the volume that matches the available supply of raw material; and there is a real opportunity for more applied research to discover useful products that can be recovered from cooking liquor.

Dimensional change with moisture change is a well-known handicap to wood in many uses, and means of overcoming this property is being studied extensively. Recent efforts to improve stability have included the use of polyethylene glycol—1000 in green wood before kiln drying—and offer a possible answer to the type of treatment needed. If it is ever possible to develop a low-cost process for stabilizing wood to avoid the expansion and contraction due to moisture changes, its utility will be greatly increased. The same problems of expansion and contraction with moisture change also exist in paper. There are many more practical problems of this type, the answers to which may well be found in fundamental research discovering methods of changing the properties of cellulose. The College of Forestry has been one of the leaders in the fields of applied research through the Empire Research Associates and in fundamental research through the Cellulose Research Institute, not to mention much outstanding research as done in other departments.

The other large user of wood besides lumber is the pulp and paper industry, an industry that has had a long and successful history of using wood pulp for an ever-increasing number and variety of useful products. The record of paper production gives ample evidence of this growth: 2 million tons in 1900; 9 million tons, 1925; 24 million tons, 1950; and 34 million tons, 1960. Many developments have contributed to this growth.

The importance of paper to the business of growing trees is apparent when we remember that over 98 per cent of the paper produced in the United States comes from wood pulp. Many other materials are produced in thin sheets, but none of them have the adaptability of paper, and none are used to any extent for writing or printing. The variety of properties and characteristics that can be produced in paper are a direct result of the unique character of the cellulose fiber found in trees and other plants. The great utility of this fiber results from its size and shape, from its chemical reactivity, and its unique property of absorbing water when mechanically beaten and rubbed. The result of this mechanical treatment, commonly called hydration, gives a gelatinous surface to the fiber and makes it adhere to other fibers, and the bond between such fibers in a sheet of paper give a strong adhesion of one fiber to another when the paper is dried. The whole paper industry is based on this one characteristic of a wood fiber.

The wide use that is made of paper is also a result of its low cost, and this in turn is due to the nature of wood. While usable cellulose fibers exist in most grasses, weeds, straw, canes, and in the seed hairs of some plants, none of these sources begin to compare to trees in cost of harvesting and processing. Trees provide large compact packages of one of the most useful fibers found in nature. The percentage of cellulose fiber to other materials is high, and the advantage of a material in such a concentrated, usable form accounts for the preponderant use of wood instead of other fibers and for the low cost of paper. Add to this the ability to grow continuing crops economically, and we realize that tree farming and papermaking are inseparably tied together and insure a strong, continuing industry.

Manufacturing processes have been constantly improved to produce paper at higher speeds with less labor and more efficient use of materials. In this way the cost of paper has been kept low so that it can be widely used for all sorts of printed communications, books, magazines, newspapers, and advertising pamphlets. Another factor, and the major one contributing to the expansion of the paper industry, is application of paper and paperboard to all types of packaging. More than half of the paper and paperboard produced is used in cartons, boxes, and shipping containers. These uses are large, for example, the idea of delivering milk in paper would have been scoffed at by our grandparents. Yet today most of the milk for home consumption is distributed in this way. Five hundred seventy thousand tons of paperboard are used in a year for this purpose. This approximates the growth of wood on half a million acres of good southern pineland.

While it may seem to you that almost everything arrives at your home in paper, there are still many challenges in packaging.

If you seek a specific challenge, the development of fully satisfactory and economical quart containers for motor oil would provide an outlet for the growth from many more thousand of acres of forest. The problem has been studied for at least twenty-five years and success has seemed close at times, but to date has not been grasped.

It might be of interest to describe in some detail a new application of paperboard which is just now being put to general use. The traditional method of distributing bananas has been to load the stems by hand labor at the Central American ports in specially built racks in special ships which deliver them to ripening houses at the major cities of distribution, where they are unloaded again by hand labor and hung to ripen. The clusters of bananas are then cut from the stems, placed in returnable trays and delivered to the stores. The bananas are frequently bruised, detracting from their appearance, the spoilage is high, and the labor, expensive. A group from the paperboard industry, experienced in packaging, spent over three years working on the problem and devised procedures which deliver bananas without the unsightly bruises, with far less loss, and at a major saving. The solution of the problem involved the development of equipment and procedures for removing the clusters from the stems, sorting, washing, and cooling the bananas, and placing them in paperboard containers at the point of collection in Central America. These containers are then trucked on pallets into the ships, from the ships to the ripening rooms, then to the warehouse or retail store, still in the same corrugated board container. In addition to eliminating damage and lowering handling costs, the stems and defective fruit are discarded before shipment, avoiding the cost of handling and disposal of these. The new procedures are in use now, and it is expected that the majority of the industry will convert to this procedure. The potential usage of paperboard for this purpose is estimated at approximately 300,000 tons per year.

The clothing market is one that has attracted more than the passing interest of the paper industry. Paper dresses have served as the subject of considerable publicity. Such a use has imaginative possibilities, but aside from the ballyhoo aspects the subject has had, it continues to receive serious attention. The non-woven fabrics are akin to paper in many ways. Paper has displaced textiles to a considerable extent for napkins and handkerchiefs. Is it unreasonable that it may compete with textiles in other uses?

Paper technology is not without its unsolved problems also. The property of imbibing water, which is the basis of hydration of the wood fiber and paper-making, is closely allied to its affinity for atmospheric moisture. The amount of water the fiber takes on from the air varies with the humidity, and unfortunately the fiber swells and shrinks as it takes on or loses moisture. This, of course, causes the sheet of paper to expand and contract and interferes with precise multicolor printing, and many other uses that require precise accuracy. To date no one has

found an economical method of stabilizing the dimensions of a sheet of paper, but who can say the challenge will not be met tomorrow.

Wood can be used as the raw material for chemicals and some important chemical industries have been built on wood. In colonial times and up to about 1820, large areas of hardwoods were cut and burned and the ashes leached to produce potash. At the peak, over two million dollars worth of this chemical was shipped to Europe per year in addition to a substantial use here for soap and glassmaking. A wasteful process, yes, but it served a purpose in times when cleared land, not wood, was the need. This business quickly folded when the much cheaper production of soda ash from salt was discovered in Europe.

Later a large and thriving industry was based on the destructive distillation of wood to produce methyl alcohol, acetone and charcoal. This industry was dealt a mortal blow by the discovery of processes for making methyl alcohol from natural gas, and distillation plants were all but done for when outdoor cooking created a big market for charcoal briquets. This added return has allowed the industry to stay alive. There is a need for other uses for the tremendous volume of hardwoods now going to waste or taking up land that could be growing valuable softwoods.

In Europe a process for the production of sugar and alcohol from wood has been used in wartimes, but the costs involved do not compete with those of other forms of starch and sugar, and the possibilities of a major chemical industry using wood for its raw material seem remote.

You are, I am sure, familiar with the very important industry using wood pulp to produce rayon, cellophane, explosives, films, plastics and lacquers. These commodities, while facing strong competition, appear to have a continuing future because of the low cost of wood pulp. The opportunity of extending the use of wood pulp to new products is being actively pursued.

The most challenging chemical utilization problem in the wood industry field is the utilization of the used cooking liquors of the chemical pulping process. This has intrigued manufacturers and researchers for many years, and I wish I were able to predict that we are at the threshold of revolutionary discoveries that will make those materials usable for something more valuable than fuel, but the needed discoveries have not been made.

The principal component of the used liquor is lignin and its products of reaction. The used liquor residues have been intriguing because they are organic compounds of complicated and unknown composition. Hope never dies, and research and discovery may some day bring the great reward. In the meantime, many worthwhile applications, with which you are undoubtedly familiar, have been developed to use a small portion of the material available.

Bark is largely in a similar position. Large quantities of bark, found on the logs carried to the mills, are removed and used as fuel. Chemical research has found several very interesting compounds in bark. Substantial quantities of the bark of certain species are being profitably used, but they are still only a minute

fraction of the supplies available. The profitable utilization of bark, other than for fuel, still remains a challenge.

These two materials, bark and waste cooking liquor, offer great opportunity for the fundamental researcher to unravel their composition and for the applied researcher to put them to a valuable use.

There is a challenge of a different nature that I would like to call to the attention of the students and recent graduates who may be present—the challenge that there is in wood-using industries for a career. Such a career can be interesting, in fact absorbing, and provide many new frontiers for exploration and accomplishment. It provides ample opportunity to be closely associated with nature and a great national resource, in doing work that is useful to the cultural and material well being of our country and its people. Having the advantages that your education at the Forestry College offers, you should give serious consideration to a career in one of these industries.

I have talked of the broad challenge of marketing wood profitably to provide an incentive for the practice of good forest management. Attention has been called to the importance of producing lumber products to meet architectural trends and to the role that research can play in the greater use of wood by the paper and chemical industries. The basic need for good and ample educational facilities is recognized. In essence, what I have hoped to say is that aggressive searching for new applications and new needs to be filled will bring forth opportunity to develop products that will fill a useful purpose and provide the profit to justify the investment and cost of growing trees and thus keep our forestlands, as well as a large group of our country's population, gainfully employed.

The Role of Basic Research

JAMES S. BETHEL

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It is a pleasure to participate in this program recognizing the fiftieth anniversary of the founding of the College of Forestry of the State of New York. I am particularly pleased to be asked to discuss with you the subject "basic research." Basic research is a major concern of the agency with which I am associated. The National Science Foundation Act of 1950 directed the Foundation to "develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences."

Before we can effectively discuss the role of basic research in advancing the forestry sciences it is necessary to start with some sort of definition of what comprises the forestry sciences and of what we mean by basic research. On at least one previous occasion I became involved in a discussion of "what constitutes forestry" and was thrown out of the game for arguing with the umpire. Accordingly, I approach the question of identification of forestry and of basic research with somewhat less confidence than that displayed by a rookie pitcher who was trying out with the New York Yankees several years ago. He got his chance in an exhibition game with the Cardinals and walked the first five men to face him. At this point Casey Stengel had seen enough and calling for a relief pitcher from the bull pen he motioned the rookie to the dugout. As he approached the bench the youngster was heard to mutter: "How do you like that? The ol' jerk takes me out just when I got a no-hitter going." With somewhat less aplomb than this I approach the matter of definitions.

I should like to propose first that forestry is of itself not a unique science or technology. The adhesive that binds foresters together professionally and in fact the quality that distinguishes forestry as an area of special scholarly interest is a concern for forests, trees and wood and for that quarter of the earth's land surface that is devoted to the growing of trees. From this viewpoint forestry is one of the great inter-disciplinary fields that are concerned with important segments of human environment. It belongs with such other great environmental groupings as oceanography, the atmospheric sciences and the earth sciences. Roger Revelle, Director of the Scripps Institute of Oceanography has said with respect to oceanography that:

"Oceanography is really not a science; it is a study of part of the earth; namely, that part of the earth which is covered with water, . . . what you really want, of course, are physicists, chemists, etc.—then you persuade them to go to sea. In order to persuade them to go to sea, you have to catch them pretty young because going to sea on a ship is not a pleasant thing, especially

if it is for a long period of time. . . . Dr. Johnson said, 'No man needs to go to sea who has the wit to get himself in jail.' "

Forestry, too, involves focusing the talents of biologists, chemists, physicists, mathematicians, engineers and the like upon the problems associated with forests, trees and wood. With our friends in the kindred fields of oceanography, the atmospheric sciences and the earth sciences we must catch them young and raise them right. What classical geneticist in his right mind would deliberately select as an organism for study one that had a normal life span several times that of his own? How many physiologists will elect to study the life processes of an organism that weighs several tons, commonly has a diameter of several feet and a height in excess of one hundred feet? There have been relatively few organic chemists challenged by the enigma of the lignin molecule. What physicist offered the glamour of studies of cosmic radiation, nuclear magnetic resonance or plasma phenomena would be content to determine how moisture moves in wood? Forestry must provide the focal point for basic research in the forestry related sciences.

The future of forestry and the forest based industries depends upon research and development. Much of this will be applied research and product development but this in turn depends upon basic research in the biological and physical sciences related to forests, trees and wood. Progress in forestry has already been seriously handicapped because of lack of basic scientific research in many areas of the forestry related sciences.

At this point it might be appropriate for us to consider what we mean by basic research. In view of the fact that basic research is a very popular subject for discussion by scientists these days, one might suppose that it has been carefully defined and that its boundary conditions have been precisely specified. Nothing could be farther from the truth. Scientists themselves cannot agree on what it is.

Several years ago, the National Science Foundation made a study to determine the extent of the Federal government's support of basic research in the colleges and universities. University officials estimated that during the year in question, they received from the research supporting Federal agencies about 85 million dollars in support of basic research. The officials in these Federal agencies estimated that they provided barely half that amount to the educational institutions for basic research during the same year. This motivated Dr. Charles Kidd of the National Institutes of Health to point out:

"Somewhere between the offices in Washington which hand out research funds and answer questionnaires and the offices in universities which receive funds and answer questionnaires, the meaning of the definitions of basic research undergoes a metamorphosis that permits one set of observers to find the quantity to be twice as large as the other observers say it is. Such a discrepancy raises a number of questions including the nature of the definitions that provide such a flexible yardstick."

In a sense, the term basic research is an abstraction and as Alexis de Tocqueville said:

"An abstract term is like a box with a false bottom; you may put in it what ideas you please, and take them out again without being observed."

A scientist is likely to view basic research in terms of his own background. The situation is somewhat reminiscent of the mountaineer on his first visit to the city. He was particularly fascinated by the asphalt streets. Scraping his foot on the surface, he remarked to his son: "Well I can't blame them for building a town here. The ground is too durned hard to plow anyway." Former Secretary of Defense Charles E. Wilson, viewing research from the peculiar vantage point of a man who came up in industry through sales once defined basic research as "what you do when you don't know what you're doing."

A more common misconception of basic research is that it is impractical research as compared with the more practical applied research. This is, of course, not true and as a thesis it can be easily discredited. The distinguished British scientist, Michael Faraday, devoted his life to basic research in the physical sciences. He was completely indifferent to the utility of his work. On one occasion when a politician asked about the practical value of his research, he disdainfully retorted, "some day you may be able to tax it!" This was a prophetic statement indeed for every electric motor and generator is a monument to the ultimate practicality of his research. Faraday himself was not ignorant of the practical potential of his work; he was simply indifferent to it.

The historic experiments with the cross breeding of red and white flowered peas conducted by the Monk Gregor Johann Mendel in the garden of an Austrian monastery were pursued solely to satisfy a great curiosity. Nonetheless, these experiments have in the final analysis had tremendous practical implications.

The President's Science Advisory Committee stated in a report issued in November 1960:

"Because basic research is aimed at understanding rather than at practical results, the layman sometimes assumes that it is entirely abstract and theoretical, and that only when it becomes a matter of industrial development does it 'come down to earth.' This is a false notion, and its falsity becomes increasingly clear with time."

If then we cannot distinguish between basic research and applied research on the basis of its practicality, what is an appropriate criterion?

The significant fact is that the motivation of the research worker pursuing basic research is a thirst for knowledge and not a concern for the practical value of that knowledge. Kenneth Petzer has stated that "the strongest human driving force in basic research is curiosity." Hans Selye the distinguished Canadian biologist defines basic research as: "the study of natural laws for their own sake, irrespective of immediate practical applicability with emphasis on immediate." Dr. Alan Waterman, Director of the National Science Foundation, has pointed out that "because basic research is done without conscious thought of what its

future usefulness may be, it is a type of research that is least understood and, therefore, the most difficult for which to find support in a world that lives chiefly in the pragmatical present."

There is much more applied research going on than basic research. It is much easier to obtain support for applied research designed to solve practical problems than for basic research designed to put questions to nature. Still, it is true that if basic research does not move ahead, applied research will also stagnate. Vannevar Bush in *Science the Endless Frontier* said:

"Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn."

The Committee on Institutional Research Policy of the American Council on Education noted:

"Basic research is analogous to a checking account in a bank. If such funds are withdrawn and not replaced, the account will soon be overdrawn. Similarly, basic research is constantly "drawn on" for the discoveries and applications necessary for progress. If our basic research account is not replenished, we face the danger of intellectual bankruptcy."

The tasks of the research workers in the broad inter-disciplinary fields are very difficult. These fields by their very nature involve all of the basic scientific disciplines and require that these be joined together and focused upon the problems of an important element of the environment. When one considers the very rapid rate of growth of knowledge in the sciences this becomes a task of tremendous proportions. The volume of scientific literature in the libraries of the world has doubled every ten years and the production of doctorates in the sciences has increased at the same rate. Ninety per cent of the scientists that ever lived are alive today and this has been true since the time of Isaac Newton.

Coincident with the growth of the traditional science disciplines of biology, chemistry, physics, astronomy, geology and the like, has come the development and growth of the important bridging disciplines. Some of the most important advances in science are today being made in such fields as bio-chemistry, biophysics, geo-chemistry, geo-physics and astro-physics. In science as in farming we are finding that "the most fertile soil lies where the old fences used to be."

In this scientific explosion—if forestry is to keep pace with the other broad inter-disciplinary fields—it must take advantage of all of the opportunities inherent in uncommitted basic research.

How can we marshall the forces required to accomplish the basic research needed if applied research and product development in forestry is to proceed at a satisfactory rate? It is clear now that this will not occur accidentally. It must be brought about through the conscious and deliberate action of the forestry community itself.

The solution of the problem of increasing basic research lies in education and this places it at the doors of our universities. The preparation of a research

worker is accomplished in the graduate school. The motivation and the encouragement must begin much earlier than that. In the undergraduate forestry school the able student with apparent potential as a research worker must be identified early in his college career. If he is interested in a career in research he should be relieved of the rigid professional course requirements and encouraged to participate in undergraduate research and independent study. Such a student ought to be encouraged to develop strength in the basic science of his choice and to continue to relate this to forestry. What may be a very appropriate curriculum for the man who wishes to practice forestry or wood technology in the forest or factory is a totally inadequate preparation for graduate study in the forestry sciences today.

It is at the graduate level that real preparation for research takes place. Here the forestry community must make every effort to encourage high-ability undergraduates with good sound science backgrounds to pursue graduate study in forestry. The best of the forestry undergraduates ought to be enrolled in the graduate programs. In addition, very able science majors from liberal arts colleges should be brought into forestry graduate programs. Yale University, Duke University and the Institute of Paper Chemistry have historically attracted good non-forestry undergraduates to graduate work in forestry. Other strong graduate programs ought to take a close look at this source of good graduate students.

If forestry is to take advantage of the full scope of the relevant sciences it must encourage breadth of training at the graduate level with little emphasis on professional training. Faculty and graduate students must be permitted to engage in basic research without regard to the immediate applicability of the results. The essence of graduate education is basic research and this is true even for the student who ultimately goes into applied research or product development.

Certainly most of forestry is concerned with practical matters. Nonetheless, its ultimate progress depends upon basic research—the search for knowledge for its own sake. We might well recall from the essays of Thomas Huxley, published about seventy-five years ago:

“It has become obvious that the interests of science and of industry are identical; that science cannot make a step forward without, sooner or later, opening up new channels for industry; and on the other hand, that every advance of industry facilitates those experimental investigations, upon which the growth of science depends. We may hope that, at last, the weary misunderstanding between the practical men who professed to despise science, and the high and dry philosophers who professed to despise practical results, is at an end.”

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Wood Product Development

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It is a real pleasure to be a part of this Golden Anniversary celebration of my College. I feel a sort of a kinship with the College—not merely as an old grad but also because it's my own Golden Anniversary year too. Hal Boyle, the newspaper columnist, says "If you have a chance to become fifty, don't pass it by. It's just worth waiting for." I'm sure that for the N. Y. State College of Forestry this Fiftieth Anniversary year will be one of many golden years in the College history.

In a way I'm not only an old grad of this College, but also I'm sort of an old timer in forest products research. I started back in the fall of '34 and have been in part time or full time research ever since. Wood products research is my life. The future life of the wood products industry is in research. So I am always glad to talk on the subject and hope to win a few more friends for wood products research.

Before completing these introductory comments I want to take advantage of this opportunity to pay tribute to the N. Y. State College of Forestry. First, of course, we've seen ample evidence these few days of an excellent present administration. Furthermore, the splendid attainments of the College also reflect the fine caliber of previous administrations. Going back to my own College days I want particularly to acknowledge the wisdom, counsel and the practical advice of my major professor, Nelson C. Brown.

GOALS FOR WOOD PRODUCT RESEARCH

The past fifteen years have been credited with almost as much advance as the previous 169 years of U.S. history. What G.I. returning from World War II would have predicted that in fifteen years the time to fly commercial planes across the country would drop from fifteen hours to five hours forty minutes? Who, in '45, would have foreseen the miracle drugs available in 1960? How many at War's end predicted that the average family would watch a picture in an electronic box forty-two man hours per week.

So far as I know only one major lumber firm was conducting research in '45; today there are dozens of medium to large sawmills conducting product development. It's been an exciting fifteen years, but the next fifteen offer greater challenges.

The population will increase 50 million.

G.N.P. will be \$1 trillion.

The future is bright for the industry ready to meet these opportunities.

The opportunity is there. What will wood products industries do with it?

What will be set as research goals?

There is the one most obvious goal for all industrial research—that goal is to make a profit for the firm that is paying the bills. But let's look at some of the other goals to be achieved in order to make that profit. One word summarizes all the other goals—"diversification."

One important area of diversification which lumber and plywood researchers should be exploring is development of refined and semi-refined wood products. Instead of boards perhaps we should be shipping factory finished interior panel; instead of dimension we should be furnishing knock down or assembled trusses; instead of plywood sheets possibly we should combine plywood, lumber and metal to make a building component. When a lumberman makes specialties or refined products he moves away from the disastrously wide price fluctuations that have plagued the lumber and plywood industries from their inception. Potlatch produces a number of such items, as do other lumbermen. During this recession, which we think is now ending, prices on those specialty items have stayed constant and demand remained satisfactory. In fact, two of our lumber specialties have had price increases.

Wood products must be devised that will give the industry greater sales in commercial, industrial, church and school construction.

Another area that could pay dividends for proper effort is in the industrial field. Years ago there was hardly a manufactured product that did not contain wood. Today products devoid of wood are legion. Research can develop markets for wood in many industrial plants such as railroad car repair, automobiles, radio and TV, just to mention a few. Here again price fluctuations will be less and long term contracts are possible.

There are opportunities in consumer items. Products for the hobbyist, fencing, garden furniture, horticultural products, camping needs, sporting goods and many other possibilities beckon. Consumer items, however, require different marketing than boards and dimension so not all lumber and plywood manufacturers should aim to diversify into this area—it has many rewards as well as many pitfalls.

Another field that will someday be rewarding is in wood chemistry. One of the problems that perhaps only chemistry can solve is the utilization of the many tons of bark available. At our own Idaho mills we have 400 tons daily. Industry simply is not working at it hard enough, perhaps hoping that the state and Federal institutions will ultimately find some answers.

PROBLEMS FACING WOOD PRODUCTS RESEARCH

Goals are closely related to problems. The goals are often attained by overcoming problems. So I want to present some of the major problems, major difficulties, facing wood products industries; problems for which the best solutions will be found in product development.

One of the most serious problems of the lumber and plywood industry is its dependence upon the housing industry. Figure 2 illustrates how dependent the lumber industry is on housing. Time after time when housing has hit a low,

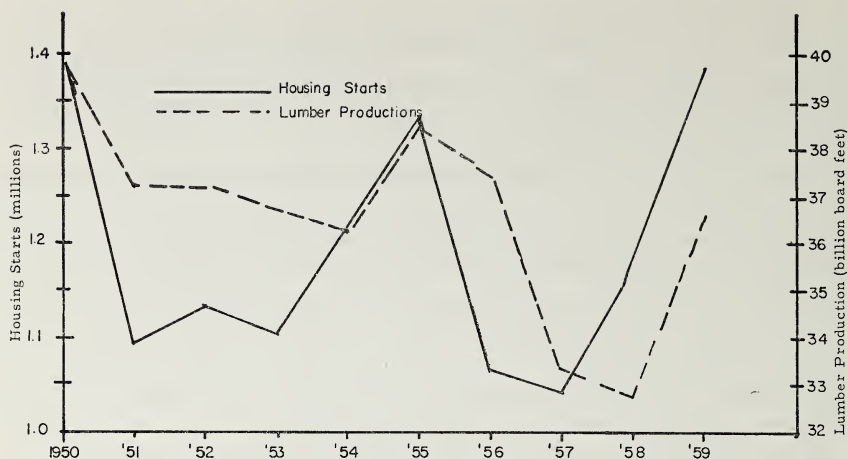


FIG. 2.—The influence of housing starts on lumber production.

other types of construction have maintained an even balance or sometimes increased. But wood has been pushed out of these other fields by codes and competition so that lumber and plywood falter as housing slows. F. W. Dodge reports total construction was practically as good in '60 as in '59. In fact, industrial and commercial construction scored notable gains. But housing fell, carrying lumber and plywood with it.

The problem is further confounded by the influence of these market swings on prices. A loss of 4 per cent in lumber sales will spark sharp price reductions. Lower sales coupled to lower prices result in drastically reduced profit. Standard & Poor reports lumber production in the month of September 1959 was $31\frac{1}{2}$ billion board feet; fifteen months later it had declined to $21\frac{1}{4}$ billion feet, a drop of 32 per cent. Lumber prices dropped 10 per cent in that same fifteen months.

Thus one of the challenges for product development is to find products with good volumes in fields other than housing.

A problem intimately related to housing and wood products dependence thereon is the extensive past inroads of competitors and the intensive continuing effort competitors are making to take still further markets in housing. Thinking back to the end of World War II, there was great excess capacity of metals in particular but other materials as well. Housing was the one great untapped market available for many of those materials. They were slow to start but by the early 50's the effect was everywhere.

1. It has been reported that lumber lost 70 per cent of its siding market in ten years.

2. F.H.A. has reported 40 per cent of its insured mortgage houses are on concrete slabs—conservatively that's a loss of 1.2 billion board feet annually.

3. The Aluminum Association reports that 25 per cent of its production is destined for construction.

4. *Business Week* stated that in 1955 there was an average of fifty-five pounds of aluminum in every house. Today it averages 175 pounds—a 350 per cent increase. In four more years the amount will be doubled again.

The struggle for home markets was highlighted in the June 18, 1960, issue of *Business Week* under the caption "Basic Materials Battle for Home-Building Market." Parts of two sentences summarize the situation—"It's clear that some of the older suppliers have suffered jolts . . . New and aggressive competition has crashed into the field."

In *The Kiplinger Magazine* of January, 1961, John Dewey tells how he believes houses will be built in 1975. He notes prefabbing and goes on to discuss materials—plastics will be used for walls, floors and roofs; aluminum sandwich panels will eliminate framework; the all steel prefab house will be revived. Wood? He doesn't even mention it.

The inroads of competition have steadily decreased per capita consumption of lumber for fifty-five years. Lumber had its peak for both total production (40 billion bd. ft.) and per capita consumption (523 b.f.) in the first decade of this century. By '29 per capita use had dropped to 268 bd. ft. It bounced back to more than 300 b.f. for one year during World War II. It's fluctuated some but the trend has been downward reaching a new low for two decades in 1960.

Lumber consumption by railroads was 1½ billion board feet in 1929; only 330 million board feet in '56. One firm sold 43 million b.f. to railroads in '38; only 4 million in '60.

Paper and paperboard have shown steadily increasing total production, somewhat in line with the increase in consumer disposable income and generally increasing per capita consumption. It's not uncommon around our office upon learning of a new baby for someone to remark "There's another 420 pounds annual increase in paper consumption." But we aren't assured of markets. Potlatch paperboard is largely a food container board. In a recent two-day survey of changes in food containers just in our small city we found three food firms market testing new plastic packages vs. paperboard packages. The *Wall Street Journal* of December 28, 1960, reports that oil firms are developing new plastics for food containers. Have you noticed that Hershey has introduced plastic bags to replace paperboard for its chocolate bars? In 1952 plastics in packages amounted to \$32 million; last year it reached \$200 million.

All the while we're losing markets the trees are growing up around us. The St. Joe National Forest in northern Idaho has doubled its allowable cut in the last five years; plans provide for doubling again by 1970; in another forty years it will be doubled again.

The Forestry Survey reports that in twenty southwest Arkansas counties there was a net increase of 4½ billion b.f. of standing saw timber in nine years. Five billion b.f. had been harvested in that area during that interval.

Irving Trust Company recently conducted a seminar mainly directed toward the cost of capital. Capital is derived from stockholders' investment through the purchase of capital stock and through retained earnings, as well as the sale of

senior securities, such as debentures and preferred stock and long and short term loans from banks, investment trusts, pension trusts, and other sources.

In this seminar the 1959 P.F.I. Annual Report was reviewed. The year 1959 was the most profitable year Potlatch has had. The Company was somewhat criticized in the seminar because even in our most profitable year, our earnings after taxes amounting to 9.3 per cent on investment were not considered to be adequate. In '60 it was down to 5.67 per cent. The bank indicated that businesses should earn 10 per cent on employed capital after taxes on an average. If the business were a hazardous one in which profits vacillated, the earnings ratio should be higher in the better years so as to provide the 10 per cent average throughout a period.

The problems the research director faces can be summarized: 1. Despite increasing wealth and population traditional markets are declining. 2. Competition for markets becomes more intense. 3. The industry does not earn enough on invested capital to attract new venture money.

Product development has the responsibility to solve these problems. At the present rate of research throughout the industry it's a losing battle.

So batten down the hatches; trim the sails; take on ballast; prepare for rough weather ahead.

THE RESEARCH AND DEVELOPMENT PROCESS

It is often said that good research makes a company successful. I'd like to rephrase that statement by emphasizing that good management makes successful research possible. It is almost universally accepted that industrial research must be the responsibility of the president or general manager.

Next to interested management, perhaps the most important ingredient of successful research is cooperation. Regardless of the worth of a product if production is disinterested or lackadaisical, new products will not succeed. The production manager who is lukewarm lets the best of ideas fail. The road between the laboratory and the market place is strewn with failures through lack of production interest.

Marketing must also cooperate. The man who talked about the world beating a path for a better mouse trap just didn't live in a modern society. Without sales we're lost. I keep reminding researchers that all we do is pile up the red ink. Only when a product is sold can a profit start. So I'm glad marketing is a part of this panel.

In summary, research organization must provide for the selection of new products, the execution of the research and the commercialization of the results.

PROJECT SELECTION

The first step on the road to a new product is selecting the best. I once knew a man whose philosophy was "When in doubt say 'No'." But saying "no" when you should have said "yes" in selecting projects can be most costly. Suppose in 1884 George Eastman had said "no" to the idea of making flexible roll films. It would have cost his company millions over the years.

Several people should have the selection responsibility and certain guides should be set. For example, does a lumber firm want to get into the consumer market? If not, things like charcoal and fertilizer should be avoided. Does a lumber firm want to diversify? If so it should seek product ideas that will lead into industrial products, new types of construction or other areas.

Is the company willing to establish manufacturing and sales facilities for an entirely different line? What kind of financing is available to build manufacturing facilities and to promote the new product? Guides are needed—it's obvious that development of a piece of electronic machinery will be profitable but even though the skills are available, it's unlikely that a lumber manufacturer should try to develop it.

With guideposts established the selection committee must answer a number of questions. One of the first is to establish that there is adequate raw material. Another step is to determine whether the customer wants it and what will he pay for it. Then an estimate of the manufacturing cost is needed to see if it can be profitably made at the price the consumer will pay. A patent search should be made not only to determine patentability but also to avoid infringement. Each case is an individual requiring many considerations. Perhaps they can all be summed up in four questions. Is it practical? Is it profitable? Is it patentable? Do people want it?

Before leaving project selection, I should mention two important guides I use. The first is to emphasize new products while de-emphasizing improvement of old ones. The latter is the easiest field in which to work especially if a man developed the old product. The successful new product, however, is generally more profitable. The second guide is to maintain close liaison with marketing groups and customers.

PROJECT EXECUTION

Research today is a productive, coordinated effort involving many skills inside and outside the laboratory. When a project is approved and assigned to research a project leader must be selected, and co-workers made available to him. Much planning is required out of which will come the work program.

A tentative schedule should be established. The needed equipment will be provided. Knowledge outside the laboratory will be made available at proper times. Funds for the program will be estimated. The project leader under the supervision of the director will conduct the work and coordinate research of others involved making sure that schedules are met where practical and that the several phases are developed in a manner that necessary results will be available when needed.

In other words, the conduct of a project includes planning, timing, budgeting, assignments, supervision and of course some work in the laboratory.

COMMERCIALIZATION

Somewhere along the line the division which will be responsible for the new product begins to take over from research. This will usually be a gradual transi-

tion. Engineers will consult researchers on equipment design. Production, sales and research will make final product specification. The merchandisers and ad agency will develop the marketing program. Accountants will get ideas from research, engineering and production on costs and check against sales prices. Many things will go on; a product manager with general responsibility can greatly smooth out this stage.

I believe more products have failed in this stage than ever failed in the laboratory. There everyone is partial to the new product; mothers it along with tender loving care. As it approaches the market, however, it has got to be sold to others both inside and outside the company. The product may be good, but these other people are busy with other things too. Furthermore, the costs of commercializing are generally much greater—some say ten times greater—than the costs of research.

There's another problem about this time too. Every research man can see one last improvement that should be made before his baby is turned over to the public. Someone has to say, "This is as far as research goes." The specs are set and the product must move out of the laboratory.

EXAMPLES OF THE RESEARCH PROCESS

One of the departments at the Lewiston, Idaho, operation was burning large quantities of wood residues. Everyone knew that these residues were being sent to the boilers but it was generally believed that the volume of material was too small to warrant the installation of the \$200,000 worth of necessary equipment to convert these residues into suitable size chips for paper making.

The measurement of the quantity of this residue appeared to be an extremely inexpensive research item so management agreed to a project with the objective of determining the quantity of chipable waste available at that point. Merely a week of measurement and computation revealed a source of \$90,000 worth of chips per year. With a payout period of just over two years, management promptly provided the necessary funds to convert those residues into valuable pulp chips.

This example is only one of several that could be cited where everybody knew of a situation but it was left up to Research to suggest that data be collected to determine the merits of spending the money to convert the residue into the valuable by-product. On this basis, I like to think of research as a catalyst in the industrial situation getting things done that were known about but which were not done until research provided the spark—the information—that established the value of an undertaking.

LAMINATED 2 x 4's

The development of the laminated 2 x 4 at Potlatch illustrates a number of steps in product development and also demonstrates some of the problems.

Shortly after the Research Department was established, management pointed to a surplus of 1 x 4's and a shortage of 2 x 4's. Research was told to try to develop

a laminated 2 x 4 as a solution to both of these problems. A general specification for the product was established. It must be:

1. Glued with exterior type glue in order to meet F.H.A. requirements.
2. Be the same cross-sectional dimensions as solid 2 x 4's.
3. Provide approximately the same strength as equivalent grade solid material.
4. The laminated 2 x 4 must be sold at the same price as the solid 2 x 4 and show a profit on the operation.

In order to be profitable while selling at the same price as solid 2 x 4's and still provide an exterior glue line, it was obvious that the least expensive exterior type glue must be used. This required the use of high temperature setting phenol formaldehyde glue. The Research efforts, therefore, were concentrated on adapting this inexpensive glue to a laminating process. In using the phenol formaldehyde glue in plywood, hot presses are used and the glue coated veneers are held in the hot press until the heat is conducted through the veneers from the hot plates to the glue lines in the layup. With 1-inch laminates, hot pressing was immediately discarded. Acid catalyzed phenol adhesives were considered but also discarded as being too expensive. Some preliminary work was done with a high frequency edge gluing machine but for several reasons this approach also did not seem satisfactory at that time.

Remembering that the cure time of urea resins had been greatly reduced in commercial operations by heating one of the faces of the wood prior to bringing the pieces together, I decided to see if a preheat system could be used to completely cure high temperature setting phenol formaldehyde adhesives. The research work on this idea was turned over to Dr. George Marra at Washington State University where a satisfactory procedure was developed.

Having established that preheat of the surfaces to be joined could fully cure high temperature setting phenols and also having available the specifications under which the operation must be conducted, the Research Department of Potlatch undertook to design and operate a pilot plant to study the idea.

The pilot plant was to be capable of producing 2 x 4's long enough to market commercially and was required to be as fully automated as possible. The development of this plant is described elsewhere so need not be described herein.

While the pilot plant studies were underway, work with the Western Pine Association was taken up to get a grade established for the 2 x 4's and also to obtain F.H.A. acceptance of the laminated 2 x 4. The Western Pine Association grade was promptly established and approved; after some delays the F.H.A. also permitted the use of the laminated 2 x 4 in F.H.A. insured mortgage homes.

During the course of the operation of the pilot plant about 1/2 million board feet of 2 x 4's had been sold to establish that the 2 x 4's could be made profitably and that the market would accept them. At the end of the pilot plant program, the matter was turned over to production and sales for commercial exploitation. At this point, we encountered another problem very typical of the lumber industry. During the course of the research and pilot plant studies, the market situation had

changed to the point that the sales department found they needed all their 1 x 4's to satisfy customers' demands for inexpensive furring strips.

One other problem is also worth mentioning. One day after showing a visitor the 2 x 4 pilot plant we stepped out of the door as a straddle buggy was dropping a load of lumber just outside of the 2 x 4 laminating operation. What was this load of lumber? It was a load of 2 x 4's that had just been sawed into 1 x 4's.

The conclusion of the comment about laminated 2 x 4's is that the customers who had purchased the laminated 2 x 4's during pilot plant like them so well and kept up their requests for so long that finally at a price for the laminated 2 x 4's \$20 per M b.f. above the price for solid 2 x 4's, the company is converting every available piece of 1 x 4 into 2 x 4's.

PLYLUMBER FLOORING

The development of Plylumber flooring is described here because it has gone through so many of the research and development activities that it is a good illustration of the research process. The general idea was to develop panelized flooring that could be quickly installed.

For the panel to be successful and competitive in cost it would be necessary that the unit combine both subfloor and finish floor.

We devised a method of applying thin strips of hardwood to two layers of softwood, the middle layer being laid at right angles to the hardwood face and the softwood back. Some preliminary cost estimates indicated that the product would be economically sound.

It should be noted that this product is very similar to one which the Tennessee Valley Authority had under development for several years following World War II. Because of several differences we felt encouraged to continue in this development despite the difficulties reported for the TVA product.

We decided that it would be desirable to make the material as thin as possible consistent with available lumber materials. At our Warren operation the manufacture of $5\frac{1}{16}$ " x 2" hardwood flooring had been a standard product for many years. We therefore decided that such materials should be used for the face, thereby using conventional manufacturing equipment. All of our operations are equipped with resaws so resawn lumber from 1-inch boards appeared to be the logical choice for the centers and backs. Thus a product about $\frac{7}{8}$ " in thickness became the basis for the work. Later for reasons of greater span and also greater stability, a second variety was introduced having the center piece made up of a nominal 1-inch board rather than a resawn board. Today, then, we have a $\frac{7}{8}$ " thickness and a $1\frac{5}{16}$ " thickness.

One of the first problems was to determine the serviceability of a cross laminated product with the thicknesses of materials that were proposed. Extensive studies showed that it would be satisfactory for use in residences.

After considering many gluing methods, it appeared best to manufacture Plylumber in single opening hot plate presses of special design. In such a press we could meet requirements of F.H.A. that the adhesive be an exterior type.



FIG. 1.—Raising a prefabricated and factory finished wall panel into position during construction of an inexpensive wooden industrial building. The fork lift is holding the frame member in place until the panel is bolted to it.

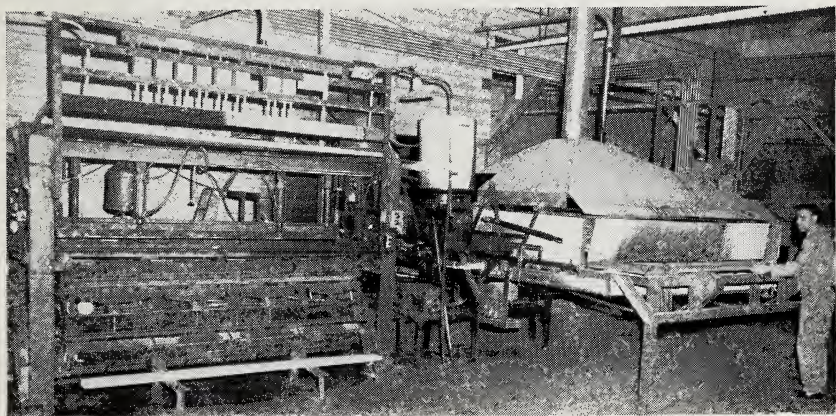


FIG. 3.—The press used in making laminated 2 x 4's using the preheat principle of curing exterior glues.



FIG. 4.—Installing Plylumber flooring.

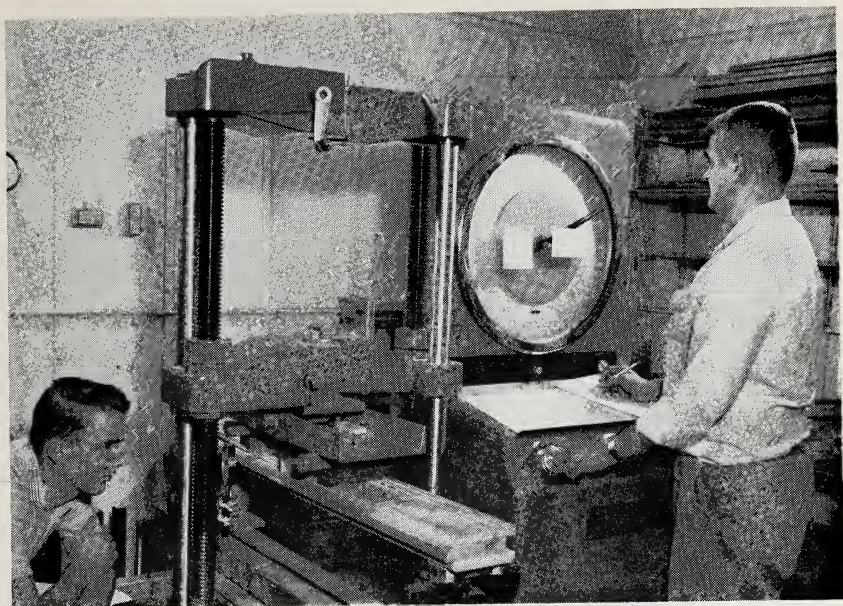


FIG. 5.—A bending test of the type used to determine the original strength properties of Lock-Deck and of the type being run constantly to assure P.F.I. customers that the original high strength properties of this product are being maintained through proper selection of lumber, control of moisture content and the exercise of proper gluing procedures. The man at the right is recording the loads on the piece of Lock-Deck while the man at the left is reading the deflections as the test proceeds.

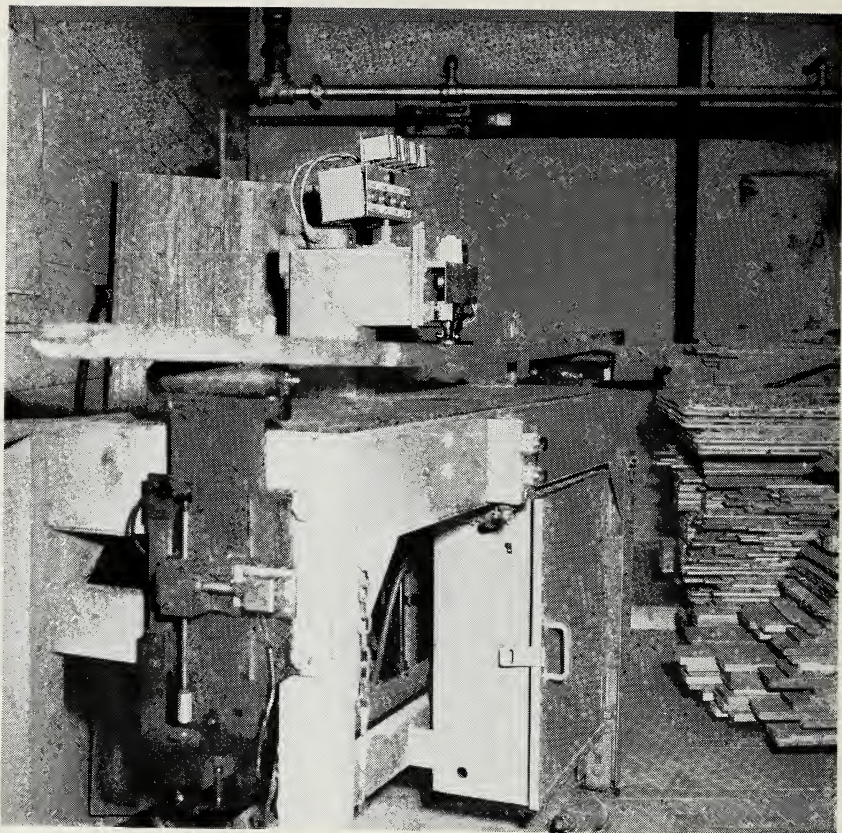


FIG. 7.—The first model of the nondestructive testing apparatus for measuring stiffness. The piece being tested has an indicated stiffness of 1,800,000 p.s.i.

A study was also made to establish best attachment of the flooring to joists. Nails, screws, special flanges underneath the floor and other devices were studied. Finally, a system of glue-nailing has been adopted. This system, when properly applied, will give a greater resistance to diagonal distortion of the floor than when diagonally laid subfloor is nailed to the joists.

Structural properties were determined both in static bending tests and full scale floor structures. The data led to our recommending a maximum span of 32 inches for the $\frac{7}{8}$ " product and 4 to 5 feet for the $1\frac{5}{16}$ " material. Under proper design situations these spans provide good economy in the construction of floor systems.

At one time there was a considerable team working on Plylumber. One man was conducting studies of the durability of the proposed glue joint between the Plylumber panel and the supporting floor joist. The pilot plant crew was considering how they could get all of the pieces comprising the face into the press, all the side joints and all of the end joints closed and what would be the best type of press to use. Conferences were underway with home builders to seek advice on the best width and length to establish—one foot wide and 16 feet long appeared to be the choice with advantages to be gained if specified lengths could be manufactured.

Pilot plant design got underway and later the pilot plant started production. At this point, we began to make sales to customers and we also approached government and code authorities for approvals.

Possibilities of patents were determined so as to prevent too much competition just after we introduce the product to the market. During the pilot plant phase, we also brought in the merchandising people and began the planning to provide adequate sales for the production that is anticipated. Finally, of course, the pilot plant operation itself is supposed to help establish the design of the production facilities.

As the pilot plant work neared completion all of the salesmen in the lumber division were advised of the new flooring and told to find markets. In the meantime, the Director of Research urged his own staff as well as the salesmen to be on the lookout for other uses. As a consequence, a possible use of this material as floors for trucks developed and this market may ultimately prove more successful than the market in housing.

At this time we have one house that is two years old and several houses 18 months old with the Plylumber flooring. It is hoped that sometime during 1961 this product will be taken out of the hands of Research and become a commercial product for the Company.

Research costs in bringing this product along over the three years on which work has been underway amounted to \$69,000. New equipment to get the plant in operation will be about \$40,000 for a production of about two million board feet a year. A new building is under construction to house the laminating equipment for Plylumber but it will also include timber and Lock-Deck laminating.

Total production will ultimately be in the range of twenty million square feet a year. In addition to providing a new product, it also appears that Plylumber

may be a very satisfactory device for getting other hardwoods into use. Furthermore, the truck flooring may put us into a new market altogether.

LAMINATED BEAMS

Another case history of some interest is that of laminated beams. Of course, custom laminators have been manufacturing highly satisfactory laminated wood for a great many years. Most of these laminators depend very heavily on a good sized engineering staff and the sale of laminated beams for specific designs. As a consequence, their product is relatively expensive, probably \$300 per M b.f. minimum price. Solid beams have a price in the range of \$100 per M b.f. Somewhere in between these two prices there seems to be plenty of room for a moderately priced laminated beam to be produced on a production basis, manufactured for inventory. A program of this nature was suggested to management but was not received with much enthusiasm. Among other things, an independent market research reported that such beams would not be widely accepted. Nevertheless, after continual urging by the Research Department, laminated beams were finally put into production. During the year 1960, the first year they were in production, the Company sold nearly a million board feet.

An advantage the sawmill has in laminating is to choose the boards best suited for laminating and move only those boards to the laminating department. All the other boards stay in regular planing mill production. The custom laminator, on the other hand, must buy lumber by grade. He must sort it and make other arrangements to utilize as fully as possible the wide range of material found in his purchased lumber.

We believe that specialties must be made from standard lumber items—we particularly avoid developments requiring special sizes to be cut in the sawmill.

LOCK-DECK

Our most successful product to date has been Lock-Deck, the tradename for a laminated roof deck. It is a three layer product, with the center layer offset to form the tongue and groove.

The product is unique in several ways. It is the first product using parallel high frequency gluing of alkaline catalyzed phenol-formaldehyde adhesives. So far as we know it's the first parallel RF curing where the glue lines are over four inches wide. It's the first high frequency cure of sixteen-foot-long glue lines. There was one feature particularly bad for me—even the pilot plant showed a profit. My bosses have expected profitable pilot plants ever since.

The product attained a sales volume of about nine million board feet in 1960, its second full year in commercial production.

A NONDESTRUCTIVE TEST FOR STRUCTURAL LUMBER

Nearly all of the standard tests for measuring the strength properties of wood and other materials are based on tests that destroy the test specimen. In order to arrive at a design stress for wood, or steel or concrete, tests are made on representative samples to provide averages which after application of certain reduction

factors provide the values which engineers use in designing their structures. The pieces actually used in construction can not be tested.

The strength of natural material such as wood varies widely, consequently, large reduction factors below test averages have been necessary so that if a weak piece of a grade gets into a structure, this weak piece will still carry the load with a margin to spare. In any one stress grade of any species the strongest piece will be five to six times as strong as the weakest. The average in a grade will be nearly three times the strength of the weakest. To make a structure safe design properties must consider the weakest pieces.

Builders and other wood users often complain that the lumber industry under-rates its product. They have reported testing pieces with up to 10 times the design strength. The explanation is that the average strengths of Douglas fir, larch and hemlock are all nearly five times the design strength. Utility Douglas fir 2 x 4 is rated at 200 p.s.i. but the strongest pieces exhibit moduli of rupture over 10,000 p.s.i. Select Structural larch has a working stress of 1900 p.s.i.; its average modulus of rupture is 9700 p.s.i. (over 5 times design); the maximum strength was 16,609 (over 8 times design).

In stiffness wood rates better because an average is used with no reduction factors. However, allowances for seasoning degrade have prevented full benefit for dry material so that allowable stiffness values of structural sizes are about 10 per cent under test values. The maximum stiffness, however, will approach or exceed twice the average.

Having these wide ranges wood can be used more efficiently if a means can be developed for measuring the strength properties of every structural piece before it is used.

Grading structural lumber is complicated, although its accuracy is reasonably satisfactory, particularly in eliminating weak pieces. Nevertheless a stress grade system to take maximum advantage of wood's strength is needed.

The poor designer who is willing to take time with wood faces a frustrating job. He not only has ten to twenty species to consider but he must also select from among a number of grade choices. One species has shown as many as forty different structural grades in its grade rule book.

So nondestructive testing looked desirable as a means to permit fuller use of strength in strongest pieces and reduce the rating in the weakest. It offers a possible means of simplifying the stress grading procedure. It would perhaps reduce the number of stress grades necessary among the species.

PROPOSED SYSTEM

Several years ago I proposed to the management of Potlatch Forests that we develop a simple nondestructive bending test at low limits of stress permitting a true measurement of stiffness or modulus of elasticity. The test would be made quickly and for greater accuracy it was proposed that the test be made with the lumber flat rather than on edge.

When R. J. Hoyle, Jr. joined the Potlatch staff, the possibilities were assigned to him. He developed the first machine which has now tested thousands of pieces of dimension. This machine can measure the stiffness on 10,000 to 15,000 bd. ft. per hour.

In observing this apparatus I became convinced that there was a close relationship between modulus of elasticity and modulus of rupture in commercial lumber. If this relationship could be established, then our simple stiffness testers also provided a device for establishing a working stress in bending. To check this theory we have made tests on over 1200 commercial pieces of structural lumber, in four different laboratories. The results confirm my earlier observation on the relationship between the modulus of elasticity and modulus of rupture.

We are therefore proposing a nondestructive testing system that provides for a direct measurement of the modulus of elasticity and an indirect measurement of working stress.

PRELIMINARY TESTS WITH WHITE FIR

The first check of the E to MOR relationship was made on lowland white fir, *Abies grandis*, which is the principal true fir species of northern Idaho. The work was done by A. D. Hofstrand and J. P. Howe, who are members of the forestry faculty at the University of Idaho.

Three hundred pieces of white fir dimension were selected at random from two grades and three sizes—2 x 4, 2 x 6 and 2 x 8 in Construction and Standard

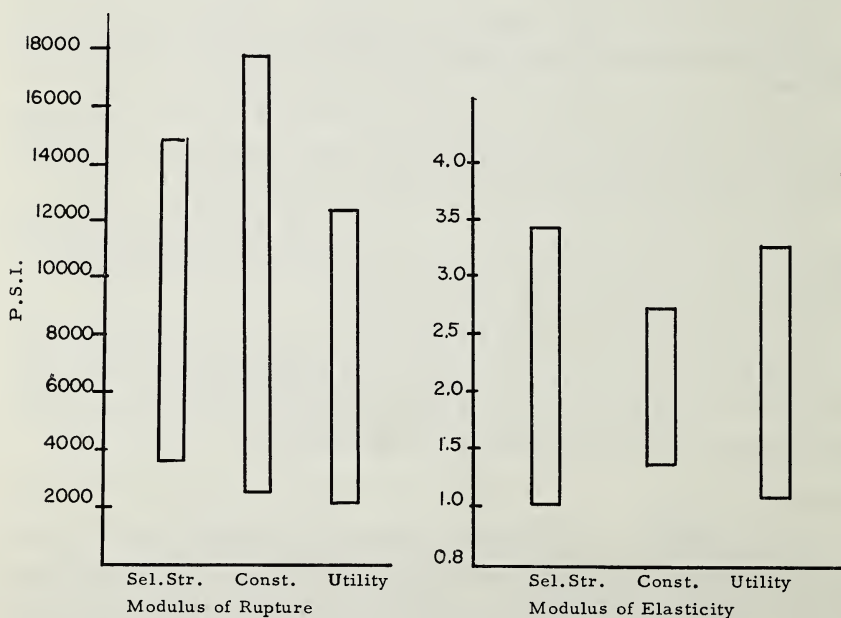


FIG. 6.—Ranges of two strength properties found in several grades of coast Douglas fir. Each bar represents 75 tested samples.

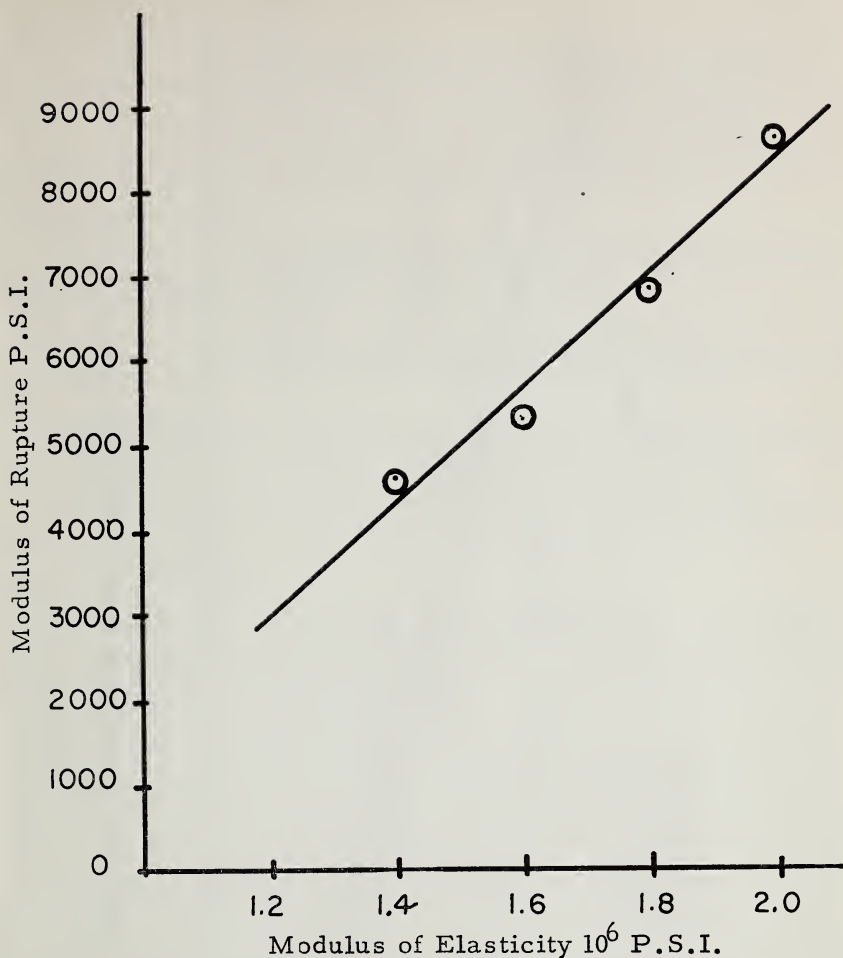


FIG. 8.—Relationship between modulus of elasticity and modulus of rupture in white fir (*Abies grandis*) 2 x 6's of two grades, Construction and Standard.

grades. This arrangement provided fifty pieces per variable. Tests were made with third point loading over seven-foot span. Modulus of elasticity was determined and modulus of rupture measured for each test specimen.

Analysis of their data led Hofstrand and Howe to conclude that there is a significant relationship between stiffness and modulus of rupture in the material they tested. Figure 8 is a simple graph showing average modulus of rupture in each of several stiffness classes for the white fir 2 x 6's in two grades. The regression line for white fir is shown in Figure 9.

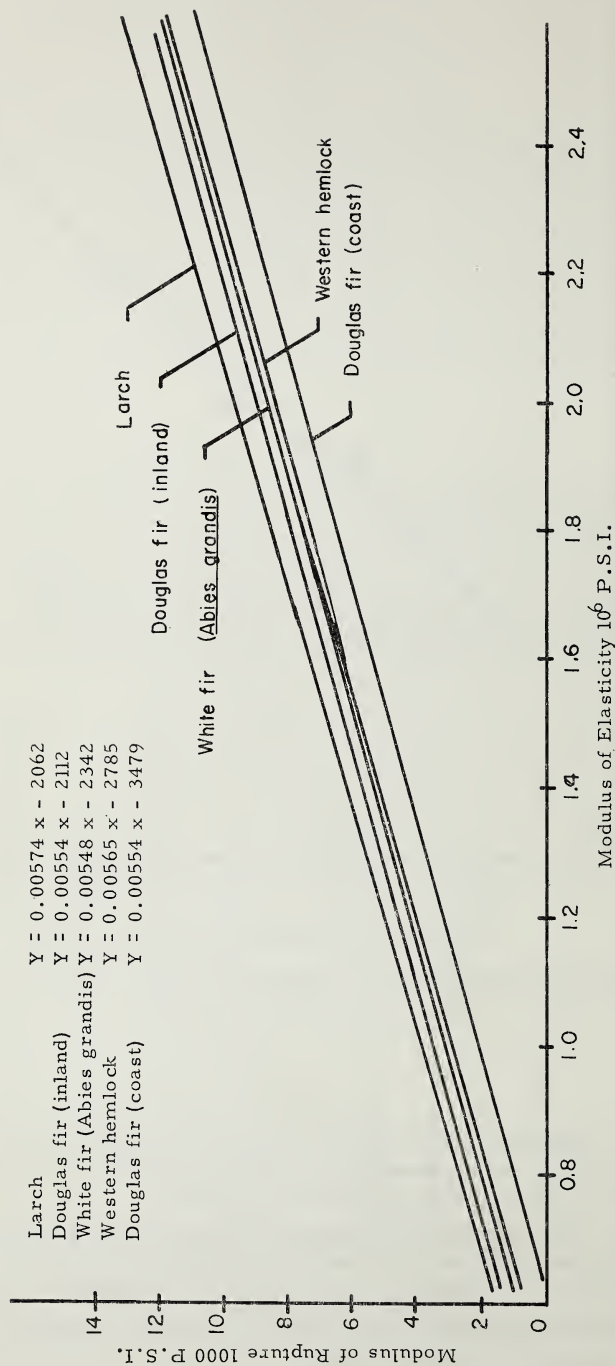


Fig. 9.—Regression lines and equations for all species tested. Each line includes all grades and sizes tested.

EXPANDED INVESTIGATIONS

The results of the white fir study encouraged us to extend the study to four other woods, namely, western hemlock, larch, and Douglas fir from west of the Cascades and Douglas fir from northern Idaho and eastern Washington. The studies were conducted at Washington State University and Oregon Forest Research Center. Dr. B. A. Jayne was in charge at W.S.U. while J. D. Snodgrass did the work at OFRC.

Variables were 2 x 4, 2 x 6, and 2 x 10, in each species; grades were Select Structural, Construction, and Utility. With twenty-five tests per variable a total of 900 specimens were tested.

Material for each variable was collected at two to four locations and taken to the laboratory where it was allowed to condition to about 12 per cent moisture content.

Bending tests were made on the flat faces with 5th point loading over an 80-inch span. Rate of loading was adjusted to provide the ASTM rate of strain.

Most of the analyses of data were done on I.B.M. computers under the supervision of R. J. Hoyle, Assistant Director of Research for Potlatch Forests.

REGRESSION EQUATIONS

This paper will not include details of the statistical analysis. The results of such a study will be available later. The intent of this discussion is merely to establish that there is a significant relationship between modulus of elasticity and modulus of rupture in commercial lumber.

Regression equations were determined by the method of least squares assuming the data were best fitted by a straight line. Further study of this assumption is planned. The regression equations for all five species are illustrated in Figure 9 which also gives the equations themselves. It must be emphasized that these equations do not indicate relative strength properties of the several species. They show only the relationship of modulus of rupture to modulus of elasticity. Thus the curves merely say that for larch the modulus of rupture at a given modulus of elasticity will be higher than for example, white fir. Similarly for any given E, hemlock has a higher MOR than coast Douglas fir.

That this situation exists between species can be further established by determining the ratio of modulus of rupture to modulus of elasticity values as shown in U.S.D.A. Technical Bulletin #479 for wood at 12 per cent moisture content. The ratios are as follows:

Larch	.0695
Inland Douglas fir.....	.0682
Western hemlock	.0678
Coast Douglas fir.....	.061
Grand fir	.057

Except for white fir the regression curve positions agree with the above ratios from Forest Products Laboratory data obtained from small clear specimens.

As an additional observation that regression curves do not indicate strength the average strength values obtained in these studies are presented in Table 1. The averages fall into the expected pattern.

CORRELATION COEFFICIENTS

The correlation coefficient is the measure of variability about the regression curve. According to Snedecor a correlation coefficient of more than 0.181 with this number of samples indicates good correlation or high degree of significance. In the relationship between E and R within the species the coefficient of correlation for all five woods tested indicates a strong relationship between E and MOR.

The coefficients of correlation are:

Coast Douglas fir.....	0.787
White fir (<i>Abies grandis</i>).....	0.748
Western hemlock	0.744
Inland Douglas fir	0.725
Western larch	0.704

These coefficients squared indicate that approximately 50 per cent of the variability of strength is accounted for by modulus of elasticity.

PROPOSED STRENGTH CLASSIFICATION

Modulus of elasticity is the property being measured. Therefore it is logical to designate the strength groups or grades by that property. Also the use of an "E" designation instead of "f" provides that machine graded material will not be confused with visually graded lumber which is designated by stress or "f" value.

The spread of E in each proposed class was arranged to give approximately an equal amount of material in each class or grade. Four hundred fifty specimens were sorted by E's ranging from 1,050,000 to over 3,000,000 p.s.i. Arranging this material into six grades would provide for about 75 per group which gave the following groupings based on modulus of elasticity:

<i>E Designation</i>	<i>Range of Modulus of Elasticity in Each Grade Million p.s.i.</i>
1.1	1.05—1.35
1.4	1.35—1.55
1.6	1.55—1.75
1.8	1.75—1.95
2.0	1.95—2.35
2.4	2.35 and higher

The species tested were the more common structural ones whose moduli of elasticity don't go below 1,000,000 p.s.i. To provide for other species, however, the group 750,000 to 1,050,000 p.s.i. has been added in Table 2. Values below the 750,000 p.s.i. at present seem too low to consider for structural purposes.

Strength values for each E class were established by applying a reduction factor to a modulus of rupture value obtained from the regression curve in each E class.

TABLE 1. Averages of moduli of rupture and elasticity for combined grades and sizes in each species.

	MODULUS OF RUPTURE	MODULUS OF ELASTICITY
	p.s.i.	p.s.i.
Inland Douglas fir	7100	1,662,000
Larch	8475	1,837,000
Grand fir*	6250	1,620,000
Western hemlock	7350	1,792,000
Coast Douglas fir	7500	1,984,000

* Adjusted to 12%. Other species tested at 12%.

The lowest point on the curve in each E class was used. For example, in the E class 1.4 of inland Douglas fir, the modulus of rupture value at E of 1,350,000 p.s.i. is used. Reference to Figure 10 shows the MOR for that E is 5400 p.s.i.

The reduction factor is the same that has traditionally been used in developing basic stresses for lumber. This factor provides for the following:

$\frac{3}{4}$ for variation

$\frac{2}{3}$ for long time loading

$\frac{6}{10}$ for accidental overload

The product of these three factors is 0.3. The factor of $\frac{2}{3}$ for load duration presumes full design load for an infinitely long period. Modern practice, however, leans toward three year loading for working stress determinations, thereby permitting a 10 per cent increase. Consequently a net reduction factor of 0.33 or $\frac{1}{3}$ results.

Design stresses are obtained by determining modulus of rupture from the regression line and applying the $\frac{1}{3}$ reduction factor. Suggested working stresses obtained in this manner are presented in Table 2. This table and the nondestructive

TABLE 2. Suggested working stresses for "normal loading" (three years at full design load) of dimension lumber sorted into E classes by non-destructive testing.

E CLASS	E RANGE	WORKING STRESSES (f)			
		Inland D. Fir	Larch	Grand Fir	Western Hemlock
10 ⁶ p.s.i.	10 ⁶ p.s.i.	p.s.i.	p.s.i.	p.s.i.	p.s.i.
0.8	0.75-1.05	650	750	600	500
1.1	1.05-1.35	1200	1300	1150	1000
1.4	1.35-1.55	1800	1900	1650	1600
1.6	1.55-1.75	2150	2250	2000	2000
1.8	1.75-1.95	2500	2650	2400	2350
2.0	1.95-2.35	2850	3000	2750	2650
2.4	2.35 and higher	3600	3750	3500	3450

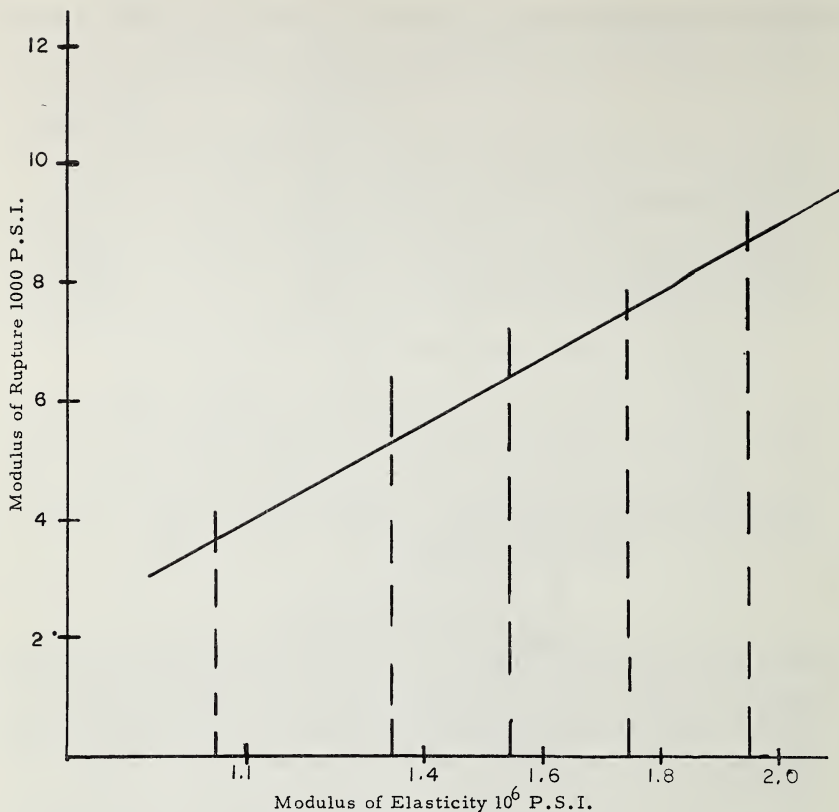


FIG. 10.—Portion of inland Douglas fir regression line divided into E classes. Modulus of rupture value to determine working stress for each class is where lower limit of E class (dotted lines) crosses regression line.

tive test for stiffness provide complete stress grading—the stiffness measurement replaces the visual grading.

Coast Douglas fir is not included in Table 2 because the dense grades of coast fir were not covered in this study. Before stress values are proposed for coast fir dense grades should be added to the data.

All of the "f" values reported in Table 2 for E classes 1.4 and higher fall well below the 90 per cent lower limit for the class. In fact as E increases the greater is the distance of "f" below the 90 per cent lower limit for modulus of rupture. Thus it is clear that the proposed working stresses are extremely conservative while still making better use of wood's strength than is possible with visual inspection.

In E classes 0.8 and 1.1, the working stress values are higher than the 90 per cent lower limit. However, in these lower ranges of E the straight line of 90 per cent lower limit passes through 0 modulus of rupture. It is obvious that

even the low stiffness pieces have some strength so the proposed "f" values are justified. The use of the suggested working stresses in E classes 0.8 and 1.1 are further substantiated by their being less than one-third the lowest test value in the case of each species.

Other systems of establishing working stresses for each stiffness grade and species were studied. One was to apply the reduction factors for long time loading and accidental overload to the lower 90 per cent limit in each category. This system providing reasonable values in the higher E classes, but with the lower 90 per cent limit becoming less than zero in the lower classes the method obviously was deficient. Values for larch obtained in this manner are compared below with values of Table 2:

E class—10 ⁶ p.s.i.	0.8	1.1	1.4	1.6	1.8	2.0	2.4
f derived from 90% lower limit (psi) ..	0	400	1150	1700	2400	2850	4000
f from Table 2 (psi).....	750	1300	1900	2250	2650	3000	3750

Another idea was to apply a small reduction factor to the lowest test value modulus of rupture in each E class. The difficulties here were that an irregular pattern resulted and also not enough tests have been made in the highest and lowest E ranges. The statistical approach as suggested overcomes both of these problems.

It has also been suggested that present f value be retained and derive an E value that corresponds. Several stress grades of Douglas fir have f values of 2100, 1950, 1700, 1450 and 1200 p.s.i. These strengths include reduction by a strength ratio due to grade. Testing nondestructively takes care of grade. In round numbers then a reduction factor of about 1/3rd is applied to the average modulus of rupture in deriving working stress. Thus if each of the f values is multiplied by 3 and the corresponding E value determined from the regression curve the values obtained for inland Douglas fir will be:

f (p.s.i.)	1950	1700	1450	1200
E (10 ⁶ p.s.i.)	1.40	1.32	1.16	1.04

Introducing some higher values for f the system could be extended as shown here:

f (p.s.i.)	3600	3300	3000	2700	2400
E (10 ⁶ p.s.i.)	2.36	2.17	2.00	1.84	1.68

This proposal, made by R. J. Hoyle, Jr., could be simplified by taking uniform increments of stress. It would be readily used by architects, engineers and designers. Its principal advantage is higher stress values in relation to stiffness. For example, for E class of 1.4 this method gives 1950 p.s.i. whereas the system proposed in Table 2 gives 1900 p.s.i. However, the system in Table 2 has some advantage because it establishes grades or classes on the basis of the property actually being measured. Also, as previously mentioned, when a nondestructive test is recognized there will still be many years during which both visual grading and machine grading will be used—there will be less confusion between the systems if the older continues with its "f" designation and the newer uses "E" classes.

APPLICATION OF THE NONDESTRUCTIVE TESTING SYSTEM

It had been hoped that the relationship of E to MOR in structural pieces would be sufficiently uniform that species variations would be insignificant. With such a situation one table of two columns would have provided designers with necessary stiffness and bending stresses. At least at present, unfortunately, it appears that species tables will be required. Nevertheless, beam, column and truss design data for stiffness and bending can be reduced to one table, to replace the five pages now required in F.H.A.'s "Minimum Property Standards" to show design values for all the grades and species produced in U.S.A.

Final grading authority rests with the regional lumber associations. Before any nondestructive system is adopted, regional lumber association grading committees will have to consider nondestructive testing. Among other items, they should investigate the number of proposed classes to determine whether more or less classes should be adopted and also establish the suitability of the ranges proposed.

MOISTURE CONTENT RELATIONS

Most studies of nondestructive testing have become concerned with the influence of moisture content of the lumber on the results of the test. Wood technologists recognize that as the moisture content is reduced below the fiber saturation point wood becomes stronger. However, these comparisons are made between pieces of the same size at different moisture contents. But what happens to a floor joist, for example, or any one piece of wood as it dries? It shrinks. Thus although a segment of a given size is stronger at 12 per cent m.c. than an equal segment at 20 per cent m.c., the shrinkage in the piece, reducing the section modulus, largely compensates for strength changes due to moisture content.

After numerous tests the P.F.I. staff concluded that a 2 x 8 surfaced at 20 per cent moisture content would bend under load about the same amount that it would deflect under the same load after drying to 12 per cent m.c. The relationship is explained by the large effect depth of a beam has on deflection. Under uniformly distributed loads, the type mostly used in design, the deflection varies inversely as the third power of the depth.

We therefore believe that the stiffness of a piece of lumber surfaced at 19 per cent will yield about the same computed or design deflection as from the same piece when dry, if the designer provides for standard dimensions. The mill surfaces at 19 per cent to $7\frac{5}{8}$ ", in service after drying to 11 per cent the piece may be only $7\frac{3}{8}$ ". The engineer, however, has computed his values at $7\frac{5}{8}$ " depth so the E measured at $7\frac{5}{8}$ " and 19 per cent m.c. should be used.

FLAT VS. EDGE TESTS

It was necessary to know how well flat tests represented the stiffness of pieces on edge such as when dimension lumber is used as floor joists. Previous tests by U. S. Forest Products Laboratory revealed that flat testing gave about 5 per cent higher stiffness values than edgewise testing.

To measure influence of knot placement 100 pieces of 2 x 8 white fir were subjected to bending tests flat and on edge. Each piece was tested in both directions below the proportional limit so that a direct comparison of stiffness in the two directions was made on the same piece. A regression equation was computed from these data to compare modulus of elasticity flat and on edge. The regression line is shown in Figure 11. The figure shows that in the lower ranges of stiffness the values are about the same but at higher E's the stiffness flat increases to 10 per cent or more than on edge. However, other tests showed a closer correlation between E and MOR when tested flat than when tested on edge.

In order to provide for these variations the designated stiffness values in Table 2 are only 50,000 p.s.i. above the lowest value in the E range of each class. Thus in most classes the designated E value is at the lowest quarter point of the range, whereas standard practice has been to use average E which would correspond with midpoint of the E range.

The proposed design values for stiffness, that is the class designations, are therefore conservative in light of past or current practices.

CONCLUSIONS

A nondestructive testing system is proposed that provides a direct measurement of modulus of elasticity. The data show that modulus of rupture is related to stiffness, consequently working stresses in bending can be determined with a stiffness test.

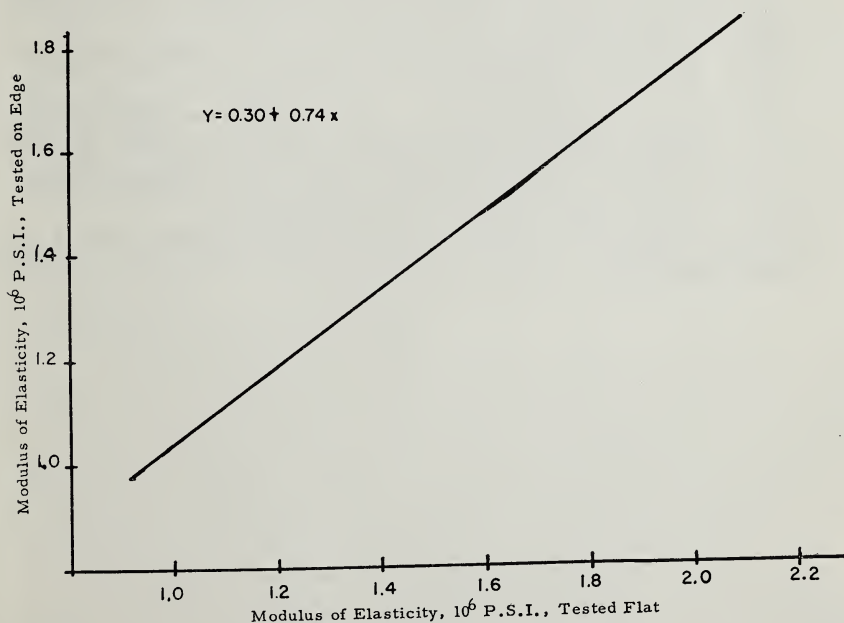


FIG. 11.—Relationship of moduli of elasticity between flat and edgewise testing of white fir (*Abies grandis*) dimension lumber.

The proposed system provides for stiffness variations between flat and edge testing by using a low value for each E class.

Dimensional changes compensate for influence of moisture change on strength properties, so no allowance for moisture content is needed.

Stiffness measurement discloses density differences therefore no visual observation for density is required.

The values of f may some day be measured with greater precision, but it is questionable that lumber manufacturers and dealers can stand a precise system with all the grades that might thereby develop. Therefore this proposed system answers a need for nondestructive testing and reduces variability within grades to only a fraction of present systems. It therefore should be given practical application now.

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Product Promotion and Marketing

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Let's look ahead. It's 1970 and you're in a reflective mood as you sit in your office. You've been going over some reports that forecast the future and you can't help but wonder: "where are we heading and how fast?"

You glance at the figures again: there are 62 million households in the nation today. Ten years ago, that figure was some 50 million. The new figure is 50 per cent more than 1950.

The same for population: 185 million in 1961, and 240 million in 1970.

Because of this, America's gross national product figures will soon be double the mid-century figure.

You scan more figures: high school population has doubled and the number of persons over sixty-five years old has increased 75 per cent. You wonder what this will do to your business. You think back over the changes in the last ten years.

Retirement housing for one thing. In 1961 the lumber industry was just beginning in this field. Now, with the increase in older persons, it's a big business.

In the last ten years, too, families have "traded up" to better houses. In 1961, trading an old house for a new one—like autos—was just a twinkle in the real estate agent's eye. Now it's commonplace. So are standard house models for various family units, removable walls, year-round climate control and new styles of furniture.

The forest products industry isn't the only industry that's been hit by this change. You have but to glance out the window to see change reflected everywhere.

You're living in a sophisticated age of super-luxury now and giant retailing has taken over. The department store of ten years ago has dissolved into nationwide shopping center chains. Internal competition with your own products is a big thing now . . . and even the salesman of 1961—outdated by pre-selling—has changed into a business consultant.

A helicopter drifts by your window—now a common way of mass transit reaching into suburbia. Stores revolve around customers who shop via push-button controls or electronic ordering systems right in their homes. Merchandise—already price-marked electronically—arrives at the retail store on its own shelf or fixture. Store window displays are TV screens controlled from a central point.

There have been changes, too, in product marketing and promotion. When you think back, you realize this field was just in its infancy in 1961.

Twilight descends on the city outside your window and the lights begin to come on. You grow nostalgic as you think back to the early part of the century. Today's concept of marketing and promotion was unheard of then . . . but then so were a lot of the common-place management functions of today.

You remember your early days in what was then just "the lumber business." The sawmill gangs worked ten and twelve-hour days, six days a week and even then couldn't keep up with a growing America's demand for lumber. No one had time to even think about new products, much less promoting them. They had their hands full filling orders.

Some of the historical facts about the lumber business come out of the past and flash by your mind: Lumber was the first industry in this country. Settlers cut the forests to meet the needs of just about the whole gamut of our civilization—roads, containers, homes, sidewalks, curbstones, wagons and ships. Lumber products were the colonies' first export . . . panels for prefabricated houses were exported from the colony of Virginia during the 1700's. In 1800, the population was a little over five million and lumber was selling for about \$8.00 per thousand board feet. By 1900, lumber production was up to 35 billion feet. Lumber hit its peak production of 44½ billion feet in 1909.

The original extent of the virgin American forest was so vast, the supply of trees so great, that at first only the best trees were cut and only the best parts of these best trees were converted into lumber. As the demand broadened and the limits of the supply could be measured, more and more of the tree was utilized. Lower grades of lumber were made and used, and the volume of wood for pulp and paper grew by leaps and bounds.

New paper mills popped up in the south and the west—and developed new markets by using certain species of trees and by-products of others. Fortunately, some companies showed real foresight and realized that timber was a crop that had to be harvested and replanted like any other crop. But it wasn't until the demand for lumber slowed down in the mid-30's that anyone had time to think about new uses of wood. And even then the new demand caused by World War Two hampered things—although it proved beyond a shadow of a doubt that wood was a prime necessity.

Some companies had foresight in another field, too—that of research. Chemists were put to work to unlock the hidden secrets in the trees and the war both hampered and helped this field. It was about this time, too, that today's concept of marketing took form because, with science developing unthought of by-products from wood, somebody had to tell the world about them. So promotion became a specialty—and all the other facets of marketing were not far behind when you realized it did no good to produce a product unless there was a need for it.

It's hard to pinpoint when all this started.

The Forest Products Laboratory was founded in 1910 but widespread interest in research didn't grow until the thirties and forties.

The general principles of restocking the forest were practiced following World War One but it wasn't until 1941 that the first Tree Farm was established.

Marketing and promotion were practiced in other industries long before the lumber industry found need for them. Actually, developers of the new by-products of the wood industry have made more use of them than lumber manufacturers—

but again, the demand for lumber was such that there was little need to think about new markets.

We gather at this symposium on April 13th, 1961, in a year that may well mark the turning point for that vague subject we term "marketing." It is noteworthy that this symposium, commemorating the 50th anniversary of the State University College of Forestry at Syracuse University, has gathered to discuss—among other things—the "Challenges of New Wood Uses." It is significant, too, that this symposium is devoted to an effort to unlocking the future, to detailing the challenges that face the forestry and forest products industries.

It takes but a glance at the past history of this institution of higher learning to see that such a symposium is only in keeping with the intellectual standards maintained here. It is appropriate that marketing be among the subjects to receive the serious attention that this symposium will accord it.

Actually, marketing is a term that is relatively new to our industry and, as with all new terms, is frequently misunderstood. So let's pause a moment for a few definitions.

First, markets: "A market is an institution designed to facilitate the transfer of legal rights and titles to ownership in goods, services and properties." A bit technical perhaps. Let's try a simpler one: "Markets are people with purchasing power."

Then, marketing: Marketing is the working together of the entire organization (research, engineering, production and marketing) to determine what the customer wants, how best to produce it, how to motivate its sale and how to deliver it.

It is based on two fundamental principles: first, customer orientation, and second, functional integration of all operating activities. Information must move *from* the customer—determining what he wants, back *to* the customer—delivering what he needs.

This procedure is designed to insure that when we sit down to help him buy, we will have products that serve his needs and desires, are pre-sold by advertising, are available in the quantities he wants, when he wants them, and are backed up by the service he knows and trusts.

That kind of ready-to-buy customers is the reason for any good marketing plan.

One authority in the marketing field lists seven basic functions of marketing and since they fit the forest products industry fairly well, let's run a quick check of them:

First is Market Research, the information center for marketing management.

Second—Product Planning, to take the knowledge of the customer and change it into saleable, profitable products.

Third—Advertising and Sales Promotion. This function is to inform, educate, and pre-sell the customer so that our personal selling efforts are more effective. We'll give this phase, promotion, more attention later on.

Fourth—Sales, is to provide the personal contact that converts marketing efforts into orders.

Fifth is Product Service—This function is to prevent customers from being ex-customers by servicing what we sell.

Sixth—Marketing Administration, is necessary to make the product available in the quantities the customer wants in locations that permit prompt delivery.

And seventh—Marketing Personnel Development, simply means we must provide the right people, at the right time, to perform the marketing function .

Some of these functions are self-explanatory, so we'll concentrate today on those that have special application to the forest products industry.

One of the main results of good marketing can be summed up as "getting the public to accept fully and continually a new product and to keep existing products appealing to the public."

This requires all the functions of marketing and all the necessary investment in the market. With a new product it means learning what the customer wants or needs, making certain it can be produced and sold and then being sure that the ultimate product meets the demand. And when you speak of the customer in this field, the term is all inclusive: before you reach the homeowner, there's the distributor, the dealer, the architect, the builder, the code authorities and other related specifiers.

An adjunct to this subject is that of creating consumer preference for your product over that of your competition. Industry-wide, this means convincing people that wood products are better than non-wood products for construction. Within the industry, it involves convincing "those convinced that wood is best" that your wood product is best of all wood products.

Let's assume, now, that we are developing and maintaining our wood products in a superior manner and that we have created an excellent demand for them. We must then turn to our next marketing principle, that of getting the product to the market place. This requires that the dealer be interested in stocking our product so he becomes a focal point of giving practical application to the principle. It also brings up the question of distribution and transportation and the dealer's inventory.

As an industry, the distribution of our lumber and plywood is a complicated process. We not only manufacture a great variety of items, but do so at a number of locations. Then we seek to distribute them efficiently all over the nation. Toward this end some firms are experimenting with the rapid processing of the necessary information by electronic computers to develop means of giving faster and better service to the dealer and ultimately the customer.

In similar fashion, the cost of maintaining heavy inventories with all the variety of items available, is becoming prohibitive to most dealers. Our industry is now providing certain strategically located wholesale facilities where they pick up small orders of unusual, or even standard items on short notice, rather than wait for a direct shipment from a mill.

Thus, by making it easier for the dealer to handle our product, he's in a better position, and mood, to move it on to the ultimate consumer.

Another marketing function we should look at is sales or personal selling, letting the world know that we have been successful in getting our efforts to the market place. Personal selling, of course, is a matter of communications and includes advertising, sales promotion, trade promotion, direct mail—all of which are inter-related.

This business of influencing the ultimate consumer is a major phase, the promotional phase of marketing, so let's glance at some of the basic principles of promotion for a moment.

Of the important phases of marketing, promotion is the phase in which the wood industry was the least active. Most lumber manufacturers expected the man who handled the finished product to promote wood, and this man, in turn, felt it was up to the manufacturer. As a result, wood went relatively unpromoted and competitors had a field day advertising that their non-wood products didn't rot, split, burn or require paint.

Actually, it's a credit to wood that it remained unchallenged for so long, and it hasn't been until recent years that markets for wood slowly and surely began to dwindle. And more recently, competitive materials have been promoted to such an extent that they have infiltrated volume markets for lumber and wood products in areas where wood is the definitely superior material.

The giant is beginning to stir, however, and we find some members of the industry beginning to strike back. Our competitors, trading heavily on isolated problems with wood, have carefully avoided mentioning the shortcomings of their own products.

For instance, the same moisture that can cause decay in wood, presents a serious rust problem for steel and causes bricks and masonry blocks to gradually deteriorate and crumble. Aluminum pits in the presence of salt air, dents easily when used as siding, has little structural rigidity for windows and—despite advertising claims—is one of the best conductors of heat and cold that we know.

The first stirrings of the giant were those of individual members of the wood industry. As individual firms saw the value of product promotion, they began to form regional groups and associations to augment the work of individual companies.

Credit should be given these individual companies and the regional organizations they formed, for they laid the groundwork, with their regional and national advertising programs, for a vast, nation-wide campaign.

They realized that a coordinated, national effort was necessary and asked the National Lumber Manufacturers Association, which represented the industry in the United States, to take over the job. NLMA, with its sixteen federated regional and wood-species associations, organized a total campaign to sell the consuming public on the concept of using all of the many lumber and wood products. NLMA argued that this type of promotion was desperately needed if the industry was to survive the pressures of competitive forces—and set out to convince the industry that a total program was needed.

The industry was convinced and the National Wood Promotion program was launched in January, 1959. The campaign was aimed at five segments of the nation's economy that influence the use of wood: consumers, builders, architects and engineers, school officials, and lumber distributors and allied groups.

The program began to advertise in national magazines, as well as magazines limited to the building trades specialties; focused general attention on important items of wood use such as basic structures, floors, windows, furniture and doors. They showed how new wood applications and the laminated arches and beams can be used to give beauty to schools, churches and commercial buildings—and at the same time cut costs.

To this was added extensive publicity featuring lumber and wood products aimed directly at the consumer. Information included how to use lumber, how to buy it and how to work with it. Architects and engineers were informed of the freedom of design permitted with wood, and that wood, and only wood, offered variety, strength, beauty and workability. At the same time, a technical field staff began making regular contacts with engineers and architects all over the country to give them the latest information on the uses and qualities of wood.

Builders and contractors were advised that they could build more house for the money with wood. School officials were advised of the advantages of building schools with wood and lumber dealers were offered information and cooperation to help them sell more lumber.

A technical services division was set up to reawaken the interest of designers, specifiers, code agencies and bulk consumers in lumber and wood products. This is being done through an aggressive program of field contacts plus the development of new and vital technical data and the preparation and distribution of technical literature.

The division's building code staff works toward development of improved building codes and a fire insurance staff has concentrated on the revisions of rate inequities that tend to discourage the use of wood in some structures.

The association is always alert to tell the public about any outstanding proofs that wood is best for construction purposes. A recent case that comes to mind is the news report of the damage caused by Hurricane Donna in Florida.

Frame buildings on sturdy foundations, with properly braced and tied roofs and walls, withstood hurricane damage most successfully. Rigid, concrete block houses frequently were blown down. Key West Building Inspector Ray Knopp had this comment: "After twenty-nine years in the construction business in the Keys, and ten years as a building official of Key West, I recommend wood-frame or pole-type construction built at least three feet above ground in all exposed areas of the Florida Keys. I make this recommendation after observing storm damage, both wind and water, not only from Hurricane Donna, but from every blow we've had for the last twenty-nine years."

While it's still too early to say how effective this program has been since it was started two years ago, there are some signs that are encouraging. Housing starts in the first ten months of 1960 were off 18 per cent—but lumber shipments

were off only six per cent. Compare these figures with some of the industry's competitors—brick was off more than 10 per cent and aluminum was off 12 per cent.

Because the results are encouraging, the program expanded. Meanwhile, other regional and trade associations are adding their own efforts to the total program. Organizations such as the West Coast Lumbermen's Association, Southern Pine Association and California Redwood Association all have carried on active promotional campaigns and will continue to do so. In the field of plywood, the Douglas Fir Plywood Association devotes all of its time promoting plywood and has been responsible for a large increase in the use of plywood by such campaigns as the nationally-circulated ads that stated that "every family needs two homes . . . one for the work-week and the other for pure pleasure."

In the field of education, American Forest Products Industries promotes scientific forest management through the Keep America Green Program and the American Tree Farm System, and collects and disseminates information about forest industries.

This is the total picture—and it's impressive: a combination of regional and national associations that are aggressively promoting the use of wood and wood products through all the means at their disposal. And back of them all, serving as the foundation and fountainhead of the promotional program, are the individual companies who pioneered the plan.

Much remains to be done, however. We are only just beginning to more effectively market our products. And we will have new products to work on as new developments give us a stronger competitive hold on the market place.

End and edge-glued lumber is providing the building industry with boards of any length and width. Laminated beams and arches are opening up entirely new fields. Right at this moment, a laminated wood tower stands near Pittsfield, Massachusetts, as one of a series of towers being tested by General Electric in an experimental model of extra high voltage. If this wooden tower proves that it can carry electrical transmission lines across our nation, a whole new market will be opened.

An aggressive industry is constantly producing new lumber products as part of the answer to increased competition. Let's quickly list some of them:

- Factory-primed and factory pre-finished wood products;

- Maintenance-free woods for interiors that only need be installed and wiped clean;

- Continuing advancements in the diversified products field—utilizing residue from primary wood products to make hardboards and particle boards;

- The myriad of products in the packaging, container and fiber field;

- Component building parts—lumber pre-cut to specified sizes to reduce field labor.

- Pre-fab construction of buildings further reduces field labor.

- Panelization, which is the use of moveable panels as room dividers. Many of these, incidentally, have the added advantage of bearing heavy loads;

And, of course, there are a host of research activities in the field of chemical utilization. Many current applications of wood are made possible by modern chemical treatments which fortify lumber against insects, decay, tropical fungus, vermin, fire, shrinkage and swelling.

And a final note of progress in the automobile age; horseshoes are now made of impregnated wood-pulp paper, laminated with powerful adhesive.

In many cases, markets for these new products don't exist as yet. There are practical uses for them but it's up to us to demonstrate their value so that the potential customer will come to know them and demand them.

To take full advantage of these opportunities to market new and better products, the industry will have to increase its efforts in marketing, even while maintaining a continuing marketing program for our present products.

The forest products industry will have to make even greater efforts, even larger investments in marketing, not only to regain the advantage we once held but to place our new products on the market place for all possible users to know.

We have the tools available to do a good marketing job. Some members of our industry are already using them to good advantage. But we must learn to do a better marketing job and each individual member of the industry, as well as every organization in the industry, must make a positive effort in this giant, coordinated campaign to be sure that no new markets are lost.

Right now we have reached a temporary lull in the demands on our products. Perhaps this is good for two reasons: it makes us realize that competition is present and must be met—and it gives us time to plan the attack. Within the next five years the crop of World War Two babies will be moving out from family homes and this new generation will crowd the market place.

It's up to the forest products industry to gear itself now so that when this demand hits we'll be properly prepared to advise it, to service it and to supply it.

We can be sure that our present research will pay off and—with proper emphasis given to marketing—the industry will pace the growth of the nation.

In two respects we are extremely fortunate: this program must be carried out by people, and we have the capable people who can do the job.

We've come a long way from the early days of the industry and the concept that a forest was something to be abandoned after it was cut and turned into lumber. We've learned to reforest the area after the harvest, and we've learned to utilize each tree for all the different and varied products we can get from it. And in learning this we've also learned that to properly use the forest we have to market it. We have to learn of new and improved products that the public wants and will use. Then we have to produce the product, promote it, sell it and service it.

We are doing this, in increasing amounts each year. We have the capable people to do this vital job. Somehow, our industry, our country, always manages to come up with the men with the know-how when it's needed.

There were far-sighted men in 1900 who saw that we might someday run out of forests unless we planted new trees. There were the practical men who

realized that each tree could be utilized more than it was and they joined with the scientist who unlocked new uses for the forests.

Each challenge provided the men of stature who rose to meet it, with each success again demonstrating that American ingenuity and the free enterprise system is and will continue to be the world's best economic system.

Today, the challenge is marketing. The tools are available to do the job, the investment required is recognized and men of stature are rising to meet this new challenge.



PART SIX

CHALLENGES IN
FIBERS AND MOLECULES



Pulping Around the World

FRANK T. PETERSON

President

The Black-Clawson Company

Metaphorically speaking, I believe we can truly say that we live today in a cellulose world. In presenting to you observations on the very broad theme of "Pulping Around the World," I feel that I must preface these remarks with two basic economic concepts.

First, today's economic renaissance throughout the world demonstrates more and more that nations must rely on indigenous raw materials for the production of finished goods in order to achieve and maintain economic selfsufficiency.

Second, the phenomenon we label with the over worked phrase "population explosion," coupled with the profound need in many countries for better living standards, provides irresistible impetus for the development of the pulp and paper industry throughout the world.

What is the role of pulp and paper in this economic and sociological renaissance? Today, world population is 2,950,000,000. In fifteen years it will reach 3,800,000,000. The most recent study of world per capita paper consumption by the Export Committee of APPA indicates that the percent average per person is fifty pounds per year. Since 1954 the growth has been at the rate of one pound per year and this rate is expected to accelerate with the spread of culture and industrialization to the many under-developed areas of the earth. When we multiply the increasing rate of per capita consumption by the predicted growth in population, we reach a demand figure for world pulp and paper production which staggers the imagination.

Most of us are familiar with the forces that make our industry grow. Pulp and papermaking is as fundamental to civilization as agriculture. It is the basic medium for the dissemination of knowledge and the creation of literature. It serves the cause of better teaching in the all important efforts to eliminate illiteracy and raise standards of living in so many underprivileged areas. It provides the instrument for recording history, for economic and political communication, and for packaging most of our food products and manufactured goods. The uses and contributions of paper are interminable.

Since I will attempt to a degree to deal with advancements in technology, I think it is altogether appropriate and deserving that we pay tribute to the men and facilities of the College of Forestry of Syracuse University and the impressive contributions they have made to the technology of pulp and paper making. Our entire industry is based on the abilities and the capacity of the men trained in institutions such as this. As industrialists we support you, we encourage you, we rely upon you, and I offer the industry's deep and heartfelt gratitude for the

work that you do here. The engineers, technicians and scientists you have trained and your contributions in research and development and the ferreting out of new processes not only advance our industry and the economic welfare and culture of our civilization but also insure in no small way the continued existence of the United States of America as a formidable industrial state in the world of free nations.

In our race for technical superiority throughout the world, we as a nation shall run behind if we do not support pulp and paper personnel training and research as carried on in technical institutions like yours. We shall fail miserably if these institutions do not continue to expand their function of supplying the specialized manpower our industry needs. Contrary to popular emotions, pulp and paper-making is not an art—it is a science, an exact science that grows more exacting every day and requires the highest caliber technicians and scientists.

Now let us examine pulping progress around the world in the light of our first concept: namely, that each nation must depend to a great extent on the utilization of its indigenous raw materials.

Throughout the world the trends in established manufacture of pulp and in today's new pulping developments support this concept. The pendulum of history swings from the production of the first papers from mulberry and papyrus to the use in more recent decades of wood fiber as the predominant raw material, and now, on the back-swing, to the resurgence of agricultural fiber pulping. One of the earliest sources of paper fiber was bamboo. Today, bamboo is once again a leading raw material for the papermaking industry of India and other east Asian countries. Several varieties of bamboo are also being employed in Latin America. Although approximately 85% of all papers are still being made from wood fibers, the advance of agricultural fibers toward a rank of increasing importance is a significant and undeniable global trend.

The swing of the pendulum is also evident in the history of hardwood pulping. The earliest chemical pulping by the original soda process was conducted on willow and poplar hardwoods. However, as chemical pulping continued to develop, it was directed mainly toward softwood utilization. So the trend continued for many years until the fairly recent revival of hardwood chemical pulping, about which more will be said in a moment.

NORTH AMERICA

In a brief round-the-world survey of raw materials for the industry, let us first take North America, or more accurately, Canada and the United States. We have three prime raw materials which will be the mainstay of our pulping in the foreseeable future. These are softwoods, hardwoods and waste paper. Waste paper, of course, is the continuing offspring of the prime sources.

With the fast maturity growth of pine in the southern United States and steady progress in intelligent farming and harvesting of these woods, we should have little cause for immediate concern in this area. In Canada and the Pacific northwest, abundant softwood timber supplies are expected to prevail in moderately

stable productivity. Inasmuch as wood shall remain our prime and predominate source of raw material, we can predict the U. S. and Canadian research in pulping processes will be mainly directed to improved methods of utilizing this traditional source of supply.

In New England and the Lakes States of this country, we can point to a relatively small but continuing revival in wood pulping since the low period of the '30's when the general recession and depletion of available softwoods combined to shut down many mills. In large part, the revival has come through increased utilization of the hardwoods native to the regions. This development would not have been possible without the research efforts of Government laboratories, paper companies, machinery and chemical suppliers, and university laboratories, like those at Syracuse. New pulping techniques emerging from these efforts have made hardwood utilization a prime, and now commonplace, source of papermaking fiber.

Pulpwood consumption statistics as compiled by the U. S. Bureau of Census emphasize the growing importance of hardwoods. In the period 1952-59, while annual softwood consumption in the North Central region dropped from 2.0 million cords to 1.8 million, hardwood consumption rose from 0.9 million to 2.0 million, overcoming the softwood loss and adding a million cords to the total consumption. Although not as pronounced, the trend is the same in the Northeastern States.

Hardwoods have played an equally important role in the rapid growth of pulping in general in the Southern States. The South now produces more than half of all the hardwood pulp in the U. S. industry.

Through tireless research, hardwoods are now chemically pulped by the kraft, neutral sulphite semi-chemical, cold soda, and modified sulphite processes. Contributing to the commercial success of these systems are the modern developments in continuous processing, which are also attaining increasing acceptance for softwood pulping.

There are still other areas of research contributing to an optimistic outlook for the North American wood supply for the next twenty-five years and beyond. These are the advancing sciences of forest management and wood genetics. Intelligent regulation of cutting and reforestation of available woodlands and growing enlightenment on the need to open and properly manage restricted woodlands will do much to increase our supplies. At the same time, the wood geneticists are predicting acceleration of the growth rate for traditional species and even selective breeding of modified varieties which will be grown for specific types of pulp needed for special paper characteristics.

WASTE PAPER

In periods of virgin fiber shortages, the North American industry, especially in the United States, makes strong demands on its waste paper supplies. In 1944, for instance, secondary fibers from waste paper comprised 36.6 per cent of the total fiber consumed. In 1959 the percentage was down to 26.5. This decline

must be attributed to the rising cost of collecting, distributing, and repulping today's waste papers in comparison with the present abundance of primary fibers at relatively low prices. However, large tonnages of waste paper continue to be consumed—9,400,000 tons in 1959 in the United States, for instance.

The long range outlook guarantees increased utilization of waste papers, as the inevitable expansion of paper production overtakes the supply of primary fibers. It is a rule of thumb that for every 4 lbs. of virgin fiber produced, there will be an increase of 1 lb. in the supply of available waste paper. This barometer indicates that in the next 15 years the repulping and reuse of waste paper will increase another 6,000,000-10,000,000 tons annually. The present 9,000,000 tons annual consumption is not a figure to treat lightly. I believe that it is not erroneous to prognosticate that the consumption by 1975 will be at least 15,000,000 tons, and probably closer to 20,000,000 tons annually.

This is a fabulous field for specialization and technological advancements. It is a field that I believe we, in the industry, have sadly neglected. We treat waste paper as a second-rate citizen in the fiber community of the industry. Quite the contrary, it is a first-rate citizen that simply needs a bath.

The problems inherent in the re-use of waste paper are three-fold: a. The cleaning or removal of entrained dirt, b. The removal of ink and printing materials, c. The removal or dispersion of additives such as plastics and asphalt, etc.

Classically, waste paper has been utilized in the rougher grades of boxboard and such types of papers. With the increased technological development of better cleaning methods, and the development of de-inking practices, more and more waste paper is going into finer grades such as magazine, printing, lithographic, photo-offset, coated paper base stock, etc.

Therefore, waste paper fiber pulping can basically be classified into two parts: 1. That to be used in the rougher types of papers and boards, 2. That to be used in the finer grades.

The waste paper fiber to be used in rough papers and boards basically needs only cleaning treatment to remove the entrained dirt, plus processes for either the dispersion or removal of the plastic type of foreign additives.

The waste fibers to be utilized for the finer types of papers must undergo de-inking, in addition to the dirt and additive removal.

The equipment manufacturers working in conjunction with the industry, are developing to a high grade of efficiency re-pulping and entrained dirt cleaning methods. This phase appears to make satisfactory progress.

We have yet much work to do in formulating processes to either remove or disperse the additives such as asphalt, plastics, and similar coatings. Further work is also required on better de-inking methods.

Last but not least, is the necessity for better control of the economics of the raw material waste paper fiber sources. The Waste Paper Utilization Council is doing much work towards the development of the utilization of better methods of collection, classification of wastes into suitable grades for various types of papers, and the establishment of standards.

I believe considerable progress will be made if the industry can create and maintain voluntarily enforced standards for precise classification of waste paper into various grades comparable to our present classification of virgin pulps.

I cannot over-emphasize the importance of recognizing waste paper as a major source of our papermaking fiber.

PULPING DEVELOPMENTS

We must recognize, however, that for many years to come, the North American industry will be basically oriented on virgin wood pulp and will direct its major energies toward improvements in mechanical and chemical pulping of wood.

In the broad sense, the pulping processes we have employed in recent decades can be classified as sulphite, kraft, semi-chemical, and groundwood. However, with the industry's increasing emphasis on research and development, these basic processes have come under critical study, and numerous improvements have been made. Among these that have lately proved successful are the following:

1. *Modified Sulphite Processes*—The traditional calcium base acid sulphite process has undergone important modifications through the application of magnesium, or ammonium, or sodium base recovery to the standard system. With the use of magnesium bi-sulphite, ammonium bi-sulphite, or sodium bi-sulphite for digestion, the cooking liquor differs from conventional sulphite in its freedom from excess sulphurous acid and thus from excess sulphur dioxide vapor pressure. With the elimination of SO_2 many advantages occur: During operation, pulp can be cooked faster at higher temperatures with greater control of yield and strength at lower operational costs. The system also eliminates problems of stream and air pollution through chemical recovery, is adaptable to a variety of hard and soft wood species, either single or mixed, permits semi-chemical or full chemical operation with a single recovery system, gives higher yield and greater fiber strength than the normal acid sulphite process, and allows production of high brightness, unbleached and easily bleached pulps.

All in all, it appears that the several types of bi-sulphite processing will be important factors in the future of sulphite pulping in North America. Companies engaged in or considering bi-sulphite pulping are showing an increasing interest in continuous digestion with its several advantages. Positive displacement type digesters, such as the Pandia, can function without hazard on bi-sulphite systems, since the danger of escaping sulphur dioxide is not present in these systems.

2. *High-Yield Sulphite*—Several mills have worked out a high yield type cooking based on the traditional acid sulphite process. This is accomplished through shorter cooking times with resulting higher hemicellulose and lignin in the cooked pulp. The higher yield is remarkable, although the resultant pulp has the inherent acid sulphite pulp disadvantage of lower tests in several physical properties, the most predominant of which are tearing strength and opacity. For such papers as newsprint and other groundwood printing grades this process has successful applications and does show promise, although development work must continue.

3. *High-Yield Kraft*—The same type of accelerated cooking has been applied to the standard kraft process with even greater success than with high yield sulphite. Considerable tonnages of high yield kraft are being produced in the linerboard mills of southern United States with yields up to 65 per cent. Strength development in these pulps, which naturally contain more lignin than fully cooked pulps, is obtained in the refining stage. To make the process economical, a balance between yield, refining power costs and resultant strengths must be determined for each mill.

It is interesting to note that the development of high yield kraft pulps is not limited to the cooking process. The combination of a lower cooking time and more effective refining action between the blow tank and the washers has produced the major proportion of the gains thus made.

In the newer systems being installed other advantages have manifested themselves, in addition to yields alone. For example, by refining immediately after the blow tank and screening before the washers, a more finely dispersed stock is presented to the washer, lending itself to better washing. Equally important is the elimination of the foam problem through pressure refining and screening. While this system tends to reduce washer capacity somewhat, it has the advantage of not having to dilute the stock after the washers for further screening requiring the use of post washing thickening apparatus.

4. *Neutral Sulphite Semi-Chemical*—Although the neutral sulphite process is not new, it is the youngest of our general group and has shown spectacular growth in the last twenty years. Much of the research in this field has been directed to continuous rather than batch processing with the result of a highly dependable low cost system which is extremely well adapted to and has been pointed mainly towards the utilization of hardwood species either singly or in mixtures.

Among its many advantages are: high yield, relatively high brightness in unbleached pulp, bleached pulp strength comparable to softwood sulphite, a high stiffness characteristic making these pulps valuable for corrugating medium, relatively low power requirement for strength development making the pulps adaptable to greaseproof and glassine papers, and relatively lower capital costs than for full chemical pulping, which permits construction of smaller plants on an economical basis.

5. *Cold Soda Pulping*—Since the introduction of modern cold caustic pulping by the U. S. Forests Products Laboratory only a little more than ten years ago, it has come forward as an extremely versatile, high yield system which promises a rapid growth—equal perhaps to that of semi-chemical. It has recently gained impetus with the introduction of several systems for continuous operation which drastically reduce the time required for impregnation of the chips with the sodium hydroxide cooking solution. As in the semi-chemical systems, fiberizing of cold soda chips is accomplished mechanically in disc refiners.

Hardwood cold soda pulps have proven exceptionally suited to the production of newsprint and groundwood printing papers, as a substitute for softwood-

groundwood. In one continuous cold soda system, employing the Chemifiner, the cold soda pulp can be produced at considerably lower horsepower demand than the equivalent tonnage of groundwood. When blended with standard groundwood in a newsprint furnish, the presence of cold soda also permits some reduction in the full chemical fiber required.

Cold soda pulps are proving their versatility as furnish in a wide variety of other grades of papers and boards, notably foodboard, corrugating medium, and tissue grades.

6. *Chemigroundwood Process*—This modified groundwood pulping system, permitting the grinding of Northeastern, dense hardwoods, hardly requires explanation before a meeting of the New York State College of Forestry. However, just for the record, this system utilizes 4 foot logs which are dropped into a large pressure vessel where a mild sodium sulphite solution is forced into the wood at 150 lbs. hydrostatic pressure, effecting a mild pulping action. The logs are thus softened so that they do not create the usual high frictional resistance in the grinding process. Grinding horsepower is reduced, the yield and strength of the fiber are increased, and a pulp with a high drainage rate results.

Chemigroundwood is a very bright and specific example of the type of contribution institutions such as this are making and must continue to make to the technology of the industry.

PULPING OUTSIDE OF NORTH AMERICA

Let us now review developments in other papermaking countries of the world, where the general trend is also toward improved processing and greater utilization of the indigenous raw materials.

In Scandinavia—Norway, Sweden, Finland—and in the Soviet Union, the preponderance of northern wood species makes it inevitable that progress in pulping follow much the same line as in North America. This is also true of Australia, New Zealand, and many other countries where wood is the major source of fiber. Much of the growing Latin American industry is already wood based and can also be expected to develop after the pattern of North America and northern Europe. It will be some years, however, before the many technological and economic problems of utilizing tropical and semi-tropical species are overcome. Nevertheless, we can look on Latin America as an awakening giant in the world fiber economy.

In round figures, let me present for a sampling of these woodpulp producing nations, their existing capacities, percent of increase through currently planned expansion, and estimated productivity by 1965 or earlier:

	Current Pulping Capacity (short tons)	Planned % Increase	Est. Prod. by 1965
Sweden	4,800,000	48%	7,100,000
Finland	3,500,000	49%	5,300,000
USSR	3,300,000	118%	7,200,000
Brazil	400,000	115%	860,000
Mexico	170,000	124%	380,000
Japan	2,700,000	74%	4,700,000
Australia/New Zealand	520,000	73%	900,000
	15,390,000	72%	26,440,000

OTHER PRIMARY FIBERS

Although 85 per cent of the present world tonnage of paper is produced from wood fibers, only fiber sources have long since proved themselves acceptable as raw materials. There is every indication that the use of agricultural fibers and other fast growing plants will increase in importance, especially in wood-poor countries which are nevertheless determined to establish and maintain a native, self-sufficient paper industry.

STRAW

In Europe, for instance, let us take the example of Holland. Practically devoid of timber resources, Holland has held a ranking position as a paper producer through intelligent utilization of straw as basic raw material to supplement its imported wood pulp. Since the end of World War II great credit in this accomplishment must be given to N. V. Research-en Adviesbureau Voor Stroverwerking, which has greatly advanced the technology of straw pulping in Holland. Around the world, straw pulping—wheat, rice or rye—promises to grow in importance even though the unfavorable economics of its procurement and storage has diminished its importance in North America. It is an established raw material in Denmark, East Germany, Hungary, Rumania, USSR, England, Argentina, Mexico, Japan, and Korea, and forms one basis of planning for the nascent industries of Egypt, Indonesia, South Africa.

In producing straw pulp, several processes apply:

In early work carried on at the U. S. Dept. of Commerce Research Laboratory in Peoria, Illinois, atmospheric cooking of straw under violent mechanical agitation in the well known Hydrapulper resulted in what is known as the Mechano-Chemical process. This has proved quite successful and the first large commercial installation was made at the Union Paper Mills in Holland. Straw is introduced into a Hydrapulper at approximately 15% consistency and cooked under agitation for approximately 40 minutes to one hour with a 10 per cent solution of sodium hydroxide. Cooking temperatures of about 190 to 205 degrees Fahrenheit are utilized.

The process produces an extremely high yield (70 to 80 per cent), remarkably strong, unbleached pulp with an extremely high pentosan content.

From the Hydrapulper the lightly cooked straw is introduced directly to a high speed refiner where the chemically softened fibers are subjected to intense mechanical attrition to break up the nodes and straw bundles. The pulp, due to high inherent bursting strength and stiffness, has proved very remarkable in the production of corrugating medium. It is also very good for straw boards, used extensively in Holland.

Some mention should probably be made of a remarkable although archaic process known as the Marsoni straw pulping system. This basically requires laborious pitching of the straw into an open pit in the ground, mixing it with slaked lime and allowing it to ferment naturally for a period of ten days or two weeks. The straw is then removed from the pit and washed and refined.

Although becoming outmoded, the rotary type digester is still widely used in Holland and other straw-rich countries for both caustic soda and neutral sulphite cooking. The cook is relatively long—four or five hours at pressures usually considerably under 100 lbs. with resulting low temperatures. Most straws have a rather high silica content which creates difficulties in the chemical recovery system. This is especially true of rice straw in which the ash content (mostly silica) runs as high as 15 per cent. Rice straw mills must therefore be planned without a recovery system.

Straw pulp produced in a batch process is quite easily bleached, and there is now some experience in Holland using continuous pulping with the Pandia digester to produce bleachable pulps efficiently at yields of 45 to 50 per cent. The trend in all new straw mills in Holland or elsewhere is toward continuous operations.

BAGASSE

Even though cereal straws have a long history as raw materials for papermaking, the world prospects now favor even greater utilization of other annual and fast growing fibers, particularly sugar cane bagasse. A modern problem in straw utilization is the high cost of collecting and storing the raw material, particularly since the advent in some countries of combine threshing, which leaves the straw stalks scattered over the growing fields. Bagasse, on the other hand, accumulates in quantity outside of a sugar mill during the grinding seasons and can be used directly in the pulp mill or can be readily baled and stored for off-season use.

The world potential for bagasse pulp is large because of its availability in suitable quantities in so many different geographic areas. The West Indies, Mexico, Central America, and most countries of South America grow sugar cane in abundance. It is a common commodity in Egypt and South Africa, in most of the countries of Southeast Asia, in the Philippines and Hawaii, and even in the Southern United States where two mills now utilize bagasse for bleached fine paper and building board production. A third mill for molded pulp products is now projected.

Bagasse formerly was limited as a papermaking raw material to coarse, unbleached papers and woods because of the high cost of removing dirt and pith from the raw stock prior to pulping or bleaching. Recently, however, an economical system has been developed combining moist depithing at the sugar mill and wet depithing at the pulp mill. This treatment yields a clean, easily pulped and bleached fiber suitable for the manufacture of the highest quality white papers.

The world count of bagasse based mills in operation or in advanced stages of construction is high:

1. Cuba—Three mills, making newsprint, unbleached papers, and bleached papers; total rated capacity 240 tons per day.
2. Peru—Two mills, making bleached and unbleached papers and cement bag paper; total capacity, 175 tons.
3. Puerto Rico—One mill, producing 300 tons per day of paperboard and bag and wrapping papers.
4. Brazil—Three mills, making writing and printing grades, corrugating medium and market pulp; total capacity, 135 tons per day.
5. Colombia—Two mills for bleached papers and corrugating medium; total capacity, 105 tons per day.
6. India—Five mills, making newsprint and wide range of papers in which the bagasse pulp is frequently blended with bamboo pulp; total capacity, 350 tons per day.
7. Philippines—Two mills for bleached papers; total of 85 tons per day.
8. Argentina—Two mills for coarse papers and bleached fine papers; total capacity, 120 tons.
9. Mexico—Three mills for tissue grades and bleached market pulp; total capacity, 140 tons.
10. South Africa—One 40 ton mill producing corrugating medium.
11. Taiwan—One 80 ton market pulp mill furnishing 45% of the total pulp consumed in Taiwan in a wide variety of papers.
12. Egypt—One 60 ton mill now under construction to supply unbleached pulp.
13. Venezuela—One 60 ton mill under construction to integrate with paper mill producing wrapping, bag, linerboard, and corrugating medium.

Bagasse pulp is also in use in building board mills in Hawaii, Australia, and England and in hardboard mills in Cuba, Taiwan and Egypt.

Even in total, these operations represent a relatively small tonnage contribution to the world fiber supply. They add up to slightly more than 2000 tons per day—about equal to the output of one of our largest Southern kraft mills. Nevertheless, they demonstrate the undeniable trend which pulping development will follow at an accelerating rate in the newly developing economies of many countries.

What other agricultural plants and grasses are entering the commercial pulping picture?

BAMBOO

Botanically a perennial grass, bamboo has become a major source of fiber in India, China, Japan, Philippines, and other southeast Asia areas. Although dry bamboo chips are extremely dense and difficult to penetrate, they respond successfully to modern pulping methods, including the continuous processes, and yield a fiber with high tear resistance and moderate bursting strength.

Especially in India, bamboo pulps are frequently blended with bagasse pulps to give a well-balanced pulp suitable for use in a wide range of furnishes.

Some pulping experts have suggested that bamboo may some day be widely cultivated as a fiber crop, perhaps even in the southern United States.

ESPARTO

This North African grass (*Lygeum spartum*) has been pulped, especially by British fine paper mills, since 1861. Until now, however, the raw material was bulk shipped at high cost from North African ports to the consuming mills. Pulping was accomplished in most instances by the soda process in small batch operations in integrated mills, except for two or three small European market pulp mills. Over the years, the economics of this procedure have grown less and less favorable. Extensive investigations of rapid continuous pulping of esparto have recently changed this picture, however. On the basis of trial pulping in the Pandia pilot pulp mill in Berlin, N. H., a 90 ton per day pulp mill is now under construction in Tunisia to produce bleached esparto pulp for world markets. Other esparto growing countries are expressing interest in following this example.

REEDS

The delta regions of the Danube and Volga Rivers in southeastern Europe produce reeds (*Phragmites communis*) that are being pulped successfully after much research, especially in finding efficient mechanical means for harvesting them. It is estimated that in the Soviet Union alone, 25 million tons of reeds are available annually. Four mills with a total output of over 800 tons per day are under construction to produce reed pulp in these regions.

As yet, other papermaking fibers are reaching commercial production only in small quantities. Among these are corn stalks, hemp, abaca, sisal, elephant grass, flax, ramie, and kenaf. Continuous pulping investigation of all these materials have produced favorable results leading to the conclusion that almost every country has some fibrous raw material which can be converted into high quality pulp and paper—usually economically. For this reason, it is true that any country with an adequate market to support an economically sized mill and with some means of financing mill construction, can develop a pulp and paper industry.

CONTINUOUS PROCESSING

In making this survey, we have made frequent reference to continuous methods of pulping. The technological advance which continuous processing has made over traditional batch digesting is evident in the wood pulping field as well as

the pulping of other fibers. No survey of world pulping developments would be complete without recognition of this development. At this moment, probably not much more than 10 per cent of the world's pulp from all raw materials is produced continuously, but the development is still in its infancy. We must all realize that continuous processing is an extremely healthy child which will gain strength and even dominance as the years go by.

There are a number of competing systems for continuous pulping—a situation which adds greater impetus to the growth of the concept as a whole. In the area of neutral sulphite semi-chemical pulping, continuous processing is already dominant. Cold soda pulping is inextricably tied to continuous processing, and each year an increasing number of full chemical pulp mills are discarding batch digestion in favor of one or another continuous system. In the broad economic picture this development contributes to world fiber economy in lower costs of pulp production and more efficient utilization of raw materials.

WASTE PAPER OUTSIDE U.S.

Our previous discussion of waste paper utilization in the United States should not leave the impression that only in this country is secondary fiber a major factor. As the rest of the world approaches our level of paper consumption, waste paper becomes an increasingly important supplement to virgin fiber everywhere.

In 1959 Great Britain formed a Waste Paper Utilization Council to stimulate progress in the same way the U. S. council functions. The 26.5% contribution of waste paper fiber to the total board and paper production of the U.K. in 1959 equals the U. S. percentage for that year. In general, the same situation prevails in all of the large paper consuming countries of Europe.

Reports delivered last fall at the Tokyo Conference on Pulp & Paper Development in Asia and the Far East stressed the high rate of waste paper recovery within the Asian countries and the extensive importation of secondary fibers by paper producing countries where virgin fiber production is still negligible.

CONCLUSION

The observations offered here have in general supported the premise that the forces of population growth and economic progress demand a continuing and rapid expansion of the pulp and paper industry throughout the world. To make the expansion possible certain factors are at work: technological investigations are constantly improving the efficiency of our traditional processes and developing new ones. The search for fibrous raw materials is moving swiftly through the surrounding forests to the annual crop farms and grasslands beyond.

The future is not uncomplicated, however. Even though fiber-rich, well established, pulp producing countries cannot possibly satisfy all of the eventual world demand, they nevertheless, can be expected to expand their industries more rapidly than newly developing countries. The reason for this is financial. The FAO survey of world demand issued in 1960 points out that for production to keep pace with demand in the period from now until 1965 an annual investment of \$1,000,-

000,000 will be necessary. In the following ten years to 1975, when the demand will be for 147,400,000 tons of paper and paperboard, the cost of building new capacity may very well reach \$1,500,000,000 per year. Perhaps half of the needed capital will be obtained and spent in North American and Western Europe. In the deficit regions of the world, the money promises to be harder to come by, and in the final analysis must come as venture capital from established governmental and private sources.

It seems safe to predict that such a vigorous and necessary industry as ours will find ways to meet the demands upon it. This means that to progress from the present world pulp production of something over 60,000,000 tons, we must add new capacity at the rate of over 4,000,000 tons per year to reach the 1975 goal of 130,000,000 tons set by FAO demand predictions.

It is a large undertaking, which I believe will follow these technical and commercial trends:

1. There will be greater emphasis on the utilization of indigenous raw materials for pulp making, especially agricultural fibers and other grasses.
2. In the basic wood growing countries of the world—primarily the United States, Canada, Scandinavia, Russia, New Zealand, etc., the stress for a long time to come will be on technological advances in wood fiber pulping.
3. Studies in wood genetics will increase, culminating in the development of improved tree varieties to meet the ultimate pulp requirements.
4. The industry will trend more and more to continuous digestion and processing.
5. The need for greater utilization of waste paper as a raw material will produce notable advancements in its collection and processing.

The entire world pulping industry has an insatiable appetite for technological advancement. I believe the ancient theory that the paper produced on the paper machines is only as good as the pulp supplied, will be more pronounced in the next decade. Let us not for a moment restrain our energies from pulping developments.

Trends and Developments in Cellulose Chemistry

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Cellulose is a generic term which comprises a large number of materials, the chemical composition of which varies over a considerable range; they are all polymeric and consist of units which belong to the class of monosaccharides. Certain members of this family are particularly important, namely those which consist essentially of beta—D—glucose and have molecular weights substantially exceeding the value of ten thousand. Most of them contain small quantities of other monomers such as mannose, galactose, xylose and arabinose but the characteristic properties of this "cellulose" in the narrower sense are determined by the presence of several hundred beta—D—glucose units in the individual macromolecules.

Systematic scientific work on the structure of cellulose started in the early years of this century after the principles of sugar chemistry had been established by the classical investigations of Emil Fischer and his school. The first problem was to establish its chemical composition in view of the many existing isomeric monosaccharides. It was approached and solved by the complete hydrolysis of cellulose down to the monomer stage and a subsequent identification of the different monomers and led to the conclusion that "pure" cellulose as it occurs in cotton consists essentially of D-glucose units. The next question concerned the way in which these units are joined together in the macromolecule; it was much more difficult to solve and it took the work of many prominent scientists over a period of almost 20 years to arrive at a satisfactory solution.

MACROMOLECULAR CHARACTER OF CELLULOSE

The first concern was to find out whether the individual monosaccharides are combined with each other by normal covalent chemical bonds like the acid and the alcohol in an ester or the aldehyde and the alcohol in an acetal or whether other interactions, such as specific coordination bonds or strong Van der Waals' forces are responsible for the insolubility, high softening point and unusual mechanical strength of cellulose. Experimental evidence appeared to exist in favor of both views and after a period of vigorous and fruitful discussions the macromolecular concept emerged around 1928 as the best representation of cellulose structure, mainly as a consequence of the work of such eminent scientists as Berl, Freudenberg, Haworth, K. H. Meyer, Sponsler, Staudinger and Willstätter.

The recognition of cellulose as a macromolecule immediately opened the question about its average molecular weight and its polymolecularity which had to be approached essentially with the aid of physical chemical methods such as measurements of osmotic pressure, sedimentation and diffusion rate and limiting viscosity ratios. The earliest, semiquantitative results of these efforts became available in the middle 1920's but it took much longer until substantial agreement was reached on the major points and there are many details not yet clarified to complete satisfaction even today. A large number of scientists working in many laboratories all over the world have contributed to the progress in this field and it would be a difficult task to give proper and deserved credit to all of them. Suffice it, therefore, in this brief review to mention that the physico-chemical studies of cellulose were initiated in the early 1920's by Herzog and Svedberg and that the results of the subsequent efforts of many other distinguished chemists and physicists are adequately described in the classical book of Ott and Spurlin on the "Chemistry of Cellulose," which appeared in 1954.

SUPERMOLECULAR STRUCTURE

In the course of these studies it became evident that the macromolecules of cellulose representing long necklaces of D-glucoses which are chemically bonded to each other by 1,4-glucosidic links exhibit, in turn, a strong tendency to assemble themselves in aggregates or bundles with a higher or lesser degree of internal order. This behavior was explained partly by the relative intrinsic rigidity of the chains, partly by the presence of no less than three hydroxyl groups per monomeric unit all of which have a distinct capacity for intermolecular bonding. The experimental studies of these supermolecular entities became essentially the subject of *solid state* research, which was carried out with filaments and films of various origin and which employed as test methods mainly the diffraction of X-rays and electrons at large and small angles, the absorption of ultra-violet and infrared radiation and the theoretical evaluation of many mechanical measurements, ranging from dynamic modulus determinations to creep studies at different moisture contents. The essential result of all these efforts was the conviction that cellulosic samples always contain domains of a very high internal lateral order which are surrounded by and embedded in a matrix of less orderly structured volume elements. The names *micellae* and/or *crystallites* became usage for the highly ordered areas, whereas the surrounding portions were referred to as *amorphous* or *laterally disordered*. This concept was then simplified (and in some cases probably oversimplified) by characterizing a given sample by a *degree of crystallinity*, which referred to the weight percentage of the volume elements having a perfect or almost perfect lateral order. The remainder was considered to be *amorphous* and it was well appreciated that there exist obvious amorphous areas of different degrees of disorder ranging from slightly distorted crystallites to domains in which the chain segments are almost completely randomly arranged in space. The picture of a *crystalline-amorphous* character of cellulose (and, for that matter, of many other natural and synthetic polymers) was surprisingly suc-

cessful in explaining most properties of these materials in the solid and moderately swollen state. Nevertheless it was obviously only a first step in the right direction and, in fact, was later replaced by the more rational concept of a *lateral order distribution function* which recognizes the gradual transition from complete order to complete disorder; its study and quantitative establishment represents one of the research approaches, which are very much alive today.

One interesting consequence of the measurements of the molecular weight of the cellulose in a given sample and the absolute dimensions of its crystalline domains was the notion that one and the same chain (with a length of 8000 Å) starts somewhere in an amorphous area, goes through a crystallite (the length of which is about 1000 Å), enters another amorphous area (which may have a length of 300-400 Å), becomes for about 1000 Å a member of another crystallite, loses its laterally ordered character in still another amorphous area and so on, because the average chain length of the macromolecules (about 5000-10000 Å) is substantially larger than the average longitudinal dimensions of the crystallites (about 800-1200 Å) and of the amorphous areas (about 300-400 Å). Thus: in ordinary (low molecular weight) compounds the individual *molecules* are *distributed over* the different *phases* (gas, liquid and crystalline) each of which is macroscopic and contains very large numbers of molecules (of the order of magnitude of 10^{16} or more) whereas in polymeric systems the *different phases*, which are submicroscopic and contain only a relatively small number of segments of each chain (of the order of magnitude of 10^2 - 10^3) *distribute* themselves over the *individual macromolecules*, each of which contains about 10^4 monomer units. These chains, therefore, are threaded through the microphases and link them into a supermolecular structure, which has the general character of a three dimensional checkerboard.

The X-ray and infrared studies also revealed the fact that this checkerboard structure can be more or less *oriented* in respect to the *shape of the sample*, such as the axis of a fiber or the plane of a film. This orientation influences the mechanical and optical properties in a significant manner and can be readily controlled by such processes as stretching, drawing, rolling or calendering.

The two concepts of *orientation* and *lateral order distribution* have allowed to correlate in a very satisfactory manner supermolecular structure and technical behavior; each of them is still in a process of development both from the point of view of experimental methods to establish its degree and of theoretical aspects in correlating it with the actual performance of the sample under given conditions.

SWELLING AND REACTIVITY

The waterbinding capacity of cellulose is one of its most important properties for the industries of cardboard, paper, cellophane, cotton and rayon; it is essentially located in the *hydroxyl groups* which each of the glucose residues has in the 2, 3 and 6 position. The two former are secondary OH-groups, the latter is a primary group; the rate and equilibrium of their hydration depends on two factors: their intrinsic capacity to bind H_2O molecules and on the degree to

which they are hydrogen bonded to each other. All available data indicate that the hydroxyl groups inside of the crystallites are so completely bonded with each other that no water is bonded at all in these areas. The moisture regain of cellulose is entirely due to the OH-groups at the surface of the crystallites and to those in the amorphous regions. This was established by a striking correlation between the degree of lateral order and the rate and equilibrium of moisture takeup. It is a significant fact that the same conditions also control the dyestuff absorption of cellulosic materials and it was on this basis that, for the first time, rational correlations between fiber structure and dyeability of cotton and rayon have been developed. Not only could the rate and equilibrium of takeup be correlated with the degrees of orientation and crystallinity but even the substantiveness of certain types of dyestuffs could be rationalized by a particularly good fitting of the size and shape of the individual dye molecule to the crystalline fine structure of the cellulose lattice.

While the processes of hydration and dye absorption are controlled by Van der Waals forces or hydrogen bonds it has been found that also the *chemical reactivity* of the three glucosidic hydroxyl groups is noticeably influenced by the structural conditions of the material. Thus, the reactivity of a sample of cotton linters or wood pulp towards xanthation, acetylation or nitration does not only depend on its average molecular weight (content of alpha cellulose) but also on the accessibility of the hydroxyl groups in the individual glucose units, which, in turn, is related to the weight percentage of the amorphous domains. The more *open* the structure the easier it is for the reagents to reach the functional groups and to interact with them chemically. If this diffusion step is very rapid, the rate of the entire process is controlled by the activation energy of the chemical process which occurs at the OH-groups; if, however, the diffusion is slow, then it becomes the rate controlling step and the speed of the entire process depends to a large extent on the lateral order distribution function of the material. This was one of the first examples to show that in polymeric systems physical structure and chemical reactivity depend on each other in a characteristic manner which, in general, does not exist with ordinary, low molecular weight substances and which is caused by the *heterogeneous* character of cellulose reactions. In some special cases, such as for acetylation and nitration the interplay of physical structure and chemical reactivity has been studied in a very systematic and quantitative manner with the general result that for processes of this type the intrinsic reactivity of a primary hydroxyl group is about twice that of a secondary OH group and that the rate of diffusion of any reagent into the unswollen crystalline areas is virtually zero. Appropriate swelling, however allows such molecules as acetic acid, acetic anhydride or nitric acid to penetrate even into the laterally ordered domains and to attach the hydroxyl groups inside of them.

DERIVATIVES

Many hundred *derivatives* of cellulose have been prepared in the course of the years by the reaction of its hydroxyl groups with various chemical agents;

they follow the pattern of the chemistry of ordinary (primary and secondary) alcohols and can be classified as ethers, esters, acetals, xanthates and others. Only relatively few of them have reached technical prominence and, as a consequence, commercial production scale.

Ether type products are prepared by allowing alkali cellulose to react with the active chlorine of an organic molecule such as ClCH_3 , ClCH_2CH_3 or ClCH_2COOH , which leads to the formation of the corresponding ethers. In this manner methylcellulose, ethylcellulose and carboxymethylcellulose are prepared, all of which are commercial products with applications in the field of watersoluble protective colloids and in the sector of moldable plastics. Other compounds of the ether type are obtained by the addition of the primary hydroxyl group of the cellulose to an activated aliphatic double bond. The only important material of this kind is the addition product of acrylonitrile to cellulose—the cyanoethylcellulose, which has found application in the modification of cotton and rayon.

Esther type products are obtained by reacting cellulose with acids and acid anhydrides; by far the most important types are cellulose nitrates and cellulose acetates with degrees of substitution ranging from 1.5 to 3.0 with propionates, butyrates and mixed esters occupying the second place. These products cover a wide range of applications from lacquers to films and from moldable plastics to fibers. Degree of substitution, average molecular weight and polymolecularity have to be carefully controlled to satisfy the conditions of any special applications. It is not very probable that, in the future, another ether or ester of cellulose will become of technical importance; the properties of many of them are well known and there is nothing in prospect which would justify their relatively high cost.

Of great importance are, at present, the xanthates of cellulose which form if alkali cellulose is allowed to react with carbon disulfide. They are the basis for the production of rayon and cellophane; their chemistry and technology is highly developed and there is not much probability for unexpected new events in their preparation and application.

Other, more complicated derivatives, such as the copperammonium and ferric tartrate complexes have played an important and interesting role in the history of cellulose chemistry but do not offer any promise for the future from the point of view of properties and costs.

Altogether it appears that the synthesis and application of *standard* cellulose derivatives which are based on normal organic chemistry does not hold much promise for the future and it was, therefore, necessary to look out for new frontiers. They appear to offer themselves by the merger of classical cellulose chemistry with the principles of polymer synthesis, particularly by the formation of addition and condensation polymers inside and around a core or backbone of cellulose. Present status and future plans for the *modification* of cellulosic materials by *grafting*, *interchain bonding* and resin deposition will now be briefly reviewed.

MODIFICATION BY CONDENSATION POLYMERS

The first attempts to combine cellulose with another polymeric system are almost forty years old and started by the treatment of cellulose with phenol-formaldehyde and with urea-formaldehyde type resin formers. The principle of all these operations is to distribute a relatively low molecular weight resin forming (polymerizable) system in the highly amorphous areas and in the interfibrillar capillaries of a cellulose fiber, such as cotton or rayon and to form the synthetic polymer *in situ* by the condensation of the resin forming ingredients. Two effects are responsible for a firm and intimate connection of the two polymeric systems. First, it is evident, that the synthetic polymer, as it grows with its branches and crosslinks will interpenetrate the macromolecular system of the base polymer and interlace with its chain segments so intimately that a very intimate connection can be expected. Second, it is also possible that the methyl groups of the growing aldehyde condensation product will react *chemically* with the hydroxyl groups of the cellulose and form acetalic bonds which link the two polymeric systems by covalent bond and another factor which produces a firm and permanent connection between them. As long as only very small amounts of the secondary polymer (1-2 per cent) are introduced into the cellulose structure the consequences are only minor, but as soon as more than 5 per cent resin are deposited in the highly accessible domains of the cellulose and in its system of interfibrillar cracks and capillaries several changes in the behavior of the treated fibers, yarns or fabrics become increasingly evident.

Since the molecular and supermolecular voids and capillaries are now essentially filled out and occupied by the resin it is understandable that the diffusion of small molecules, such as water or dyestuffs considerably slowed down and, as a consequence, the moisture pick up and the dye acceptance of the material is reduced. If the fabric is dyed before the deposition of the secondary polymer in its supermolecular capillary system the resin treatment causes improved dimensional stability in the face of environmental moisture changes in the atmosphere. The presence of a rather highly crosslinked, three dimensional resin inside of the cellulose increases the stiffness of the system, delays the formation of creases and pleats and promotes their reversible disappearance because of the improved springiness of the polymeric matrix. In fact, the initial effects of most of the existing *creaseproofing* treatments of this type are quite pronounced and the only disadvantage of them is that the secondary resins, particularly those made from urea or melamine with formaldehyde are somewhat sensitive against hydrolysis and are gradually removed in the course of repeated laundering with hydrolyzing agents at elevated temperatures.

Similar to phenol and urea formaldehyde resins it was also possible to deposit in the superstructure of cellulose condensation products of the polyester and polyamide type. The results are similar as far as the property changes and also as far as the sensitivity against hydrolytic action is concerned.

Recently these earlier efforts have been followed by the incorporation of many other condensation type polymers into cellulose, such as epoxide diisocyanate

and silicone resins, alone or in combination with each other. This has led already to many modified cellulose textiles and is going to lead to many more in the near future. Particularly interesting are those which exhibit high hydrolytic stability such as the epoxy and silicone types.

GRAFTING OF ADDITION POLYMERS

The best method to arrive at secondary polymers of very high hydrolytic stability would evidently be the deposition of a vinyl-acrylic or diene type polymer in the superstructure of cellulose. This has been accomplished in many cases by *grafting* vinyl type polymers to the cellulose chains. The simplest, although not the most efficient, way is to swell the cellulose with a vinyl type monomer or a mixture of them and to polymerize these monomers while they are embedded between the segments of the cellulose chains.

Rather extended experience of grafting of vinyl polymers onto each other has shown that there results a direct *chemical* interconnection between the two polymers because of *chain transfer* processes in the course of which a free radical site is transferred from a growing chain of one of the two polymers, say polymer A, to a chain of the other polymer—say polymer B—with the resulting chemical attachment of a branch of *poly A* to a backbone chain of *poly B*.

The same principle has also been applied to cellulose and, in fact, it was possible to graft a number of vinyl type polymers, such as styrene, vinylchloride, acrylonitrile and butadiene to cellulosic objects by swelling the fiber or film in the monomer and initiating the vinyl-type polymerization either with ionizing radiation or with free radical forming catalysts, such as peroxides or azodinitriles. The disadvantage of this method is the formation of a relatively large amount of vinyl-type polymer which is not chemically attached to the cellulosic framework, because many chains are started by the fragments of the initiating catalyst and terminated by chain transfer or by recombination with chains of the same type. Depending upon the experimental conditions it has been found that about half of the mass of the vinyl polymer is chemically bonded to the cellulose whereas the other half is independent and only mechanically entangled with it. Grafting of hydrophobic vinyl-type polymers such as styrene or acrylonitrile causes very noticeable changes in the moisture absorption and the related dimensional stability of the cellulosic base material to which they are attached. But the presence of the independent polymer represents a disadvantage because of the fact that it is slowly removed in the course of laundering and pressing.

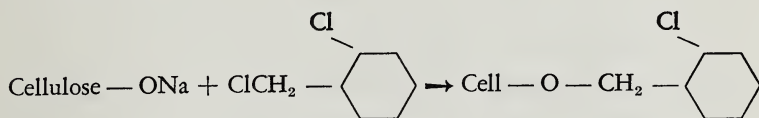
One has, therefore, looked for other, more efficient ways to perform the grafting of an addition polymer to a cellulosic framework and discovered many such possibilities. A few of the more important ones will now be enumerated.

Linear epoxide type addition polymers can be attached to cellulose directly through its primary hydroxyl groups. Introduction of only one ethylene oxide to each glucose leads to the very hygroscopic hydroxyethyl cellulose which still can be defined as a classical cellulose derivative but prolonged reaction of cellulose with ethylene—or propylene oxide—causes the formation of longer and longer

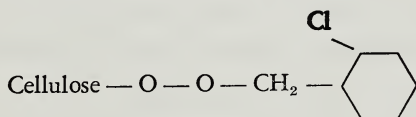
epoxidic chains so that it has been possible to add very high percentages of epoxy-type resins through ether bonding to cellulosic samples. The addition of such large quantities of foreign material disrupts the original cellulose structure and renders the products easily swellable and very soluble in water and many organic solvents. If bifunctional epoxides are being added, such as one of the Epons or butadiene-diepoxide the systems become curable and can be converted into hard, insoluble and infusible masses which also can be visualized as being cellulose filled and reinforced Epon resins.

Many ways have been found to grow vinyl-type addition polymers directly from the backbone chains of a cellulosic material. One is to introduce a small amount (1-2 per cent) of bromine into the cellulose, swell the brominated system with the monomer, the polymer of which one wants to attach and initiate polymerization through irradiation with a wavelength which only dissociates the bromine atoms from their positions but does not affect other bonds in the system.

Another way is to introduce a peroxidic or hydroperoxidic group into cellulose and to produce a free radical site by the dissociation of this group. If one allows, for instance, alkalicellulose to react with orthochlorobenzylchloride, one obtains the corresponding ether

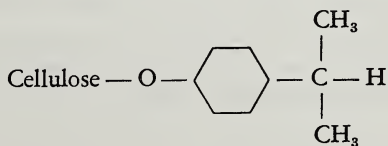


which can be readily oxydized to give the peroxide

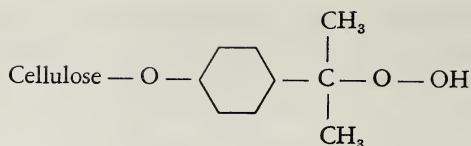


which in turn, can be dissociated thermally or with the aid of an appropriate redox system to give a free radical type site directly attached to the cellulose which is very efficient in initiating additional polymerization of any vinyl— or acrylic type monomer.

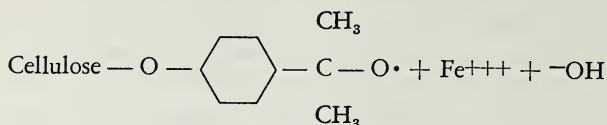
Or, one can react paraisopropylbenzoylchloride with alkali cellulose to obtain:



These groups, which are only introduced into the cellulose in small quantities, such as 1 or 2 percent, are readily oxydized into hydroperoxyl groups.

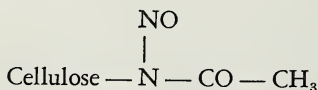


which, in turn, can be dissociated with the aid of a reducing agent such as ferrous ion or bisulphite ion to give

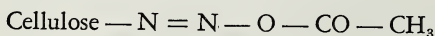


It can be seen that the only free radical type reactivity remains attached to the cellulosic framework and that, therefore, all vinyl polymer chains are growing directly from the cellulose without any formation of unattached polymer.

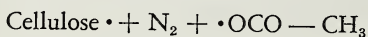
Still another way to reach the same goal is to convert aminocellulose into the aminonitrosoacetate.



which spontaneously rearranges to the diazoester



If a cellulose sample containing a small percentage of such groups is swollen with a vinyl monomer and then exposed to a low pH, the diazoester splits into



and produces free radical sites directly at the cellulose which initiate vinyl-type polymerization very efficiently. The free acetylradical $\text{CH}_3\text{COO} \cdot$ is very efficient in picking up a hydrogen atom from the cellulose and produces another free radical site directly at the cellulose chains, which grows a chemically attached polyvinyl chain.

This brief review shows that there exist many different ways to graft a wide variety of vinyl and acrylic type monomers to cellulose. Some of the resulting products have already been studied and have shown interesting properties for the application in the field of fibers, plastics and coatings but many other combinations are still possible and it can be expected that much of the future of cellulose chemistry lies in the field of grafting.

Research Needs in the Pulp and Paper Industry

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This Fiftieth Birthday is a memorable occasion for the New York State University College of Forestry at Syracuse University. May I convey to the College of Forestry, its faculty, students, and alumni, sincerest greetings and congratulations from the University of Washington, and especially from the University of Washington College of Forestry, its faculty, students and alumni, where we also are celebrating a birthday of our University—the 100th it happens. May your College, during the next fifty years, continue to make the outstanding contributions in teaching and research which have marked its now half-century of history.

It is apparently true that paper was made in China some 2000 years ago, from grass by mechanical and microbiological means. But it was only some 100 years ago when the modern paper and pulp industry began, i.e., when machines and chemicals came into substantial use to assist in securing fibers from wood, and to remove lignins, and to purify cellulosic fibers. Thus the New York State University College of Forestry is now about half as old as the modern pulp and paper industry itself. During this half century, developments have occurred in all the world around us and, indeed, in the pulp and paper industry also.

Today I am to speak about the research needs of the pulp and paper industry and this is a challenge indeed. In view of all of the achievements we have seen in recent years, I am, of course, cautious about saying very much in detail, or very much about prospects beyond the immediate future. But although our society moves fast, and may well move even faster in the future, we must take courage and time to plan and to prepare. The College is to be commended for becoming fifty years old and thereby providing an especially good reason for today's discussions.

By my definition, the pulp and paper industry starts with the seed and the tree in the forest; proceeds through the growing and harvesting of trees, the separating of woody tissue from bark and other materials, the processing of these materials into pulp, paper and other cellulose products or other by-products, and finally the distributing of these products to the consumer. To conduct these operations efficiently and profitably, contributions are required from many persons of widely different talents and associations, and I include all of these activities and persons when I speak in relation to the research needs of the industry.

The research needs of the industry are those requirements which need to be satisfied to maintain the industry viable as a strong competitor and as a sound and profitable contributor of useful products to the people of the nation.

THE NEED FOR INCREASED RESEARCH ORIENTATION

For survival and growth, the industry must, of course, continuously reevaluate its positions, and then plan and act in accordance with the best conclusions and proposals which can be developed from the information at hand.

All of us, in this room, accept this premise although we may not always act upon it. But there was a time, at least during the Middle Ages, when this was not generally accepted. One can argue that it was the fairly widespread acceptance of this philosophy, beginning at various places in the 12th to the 16th centuries, which has contributed to the nearly incredible changes which have occurred during the last few centuries. For example, consider world populations. It is estimated that at the time of Christ the population of the world was about 200 million and this population level apparently remained about constant for the next 1,800 years. But about 1800 or 1850 the population of the world began to increase rapidly—perhaps primarily because of some acceptance of a rational philosophy giving rise to higher food production and better medical care—world population increased from 200 million in 1800 to about 2 billion in 1930, and now in 1961—it is estimated at 3 billion, i.e., a 50 per cent increase in 30 years. A UN Committee estimates that the *rate* will soon reach 2 per cent per year, or about twice the rate just before World War II. On this basis, the 3 billion people in the world today will become 4 billion by 1980.

These “aside” remarks about world population, as well as other statistics, of course suggest the availability of steadily expanding markets.

But my point at present is not related to these attractive future market possibilities, because one can equally well argue that effective application of the Rational Method in a different industry may lead to products which may actually take markets away from the pulp and paper industry. My part is to emphasize the essential importance and power of *The Rational Method* in relation to all phases of our society and to the pulp and paper industry in particular.

One can say that research is the first step involved in the carrying out of the Rational Method and, for research, the dictionary meaning is “. . . careful, systematic, patient study and investigation in some field of knowledge, undertaken to establish facts or principles.” When this research has produced facts or principles by which predictions can be made about the outcome of several alternative courses of action, one can then proceed to compare the relative advantages or disadvantages associated with these courses of action. According to the next step in carrying out the Rational Method, one *decides* to act, and does act, to carry out what appears to be the most desirable course available.

Thus the Rational Method is based upon two elements: *firstly*, *research* to permit predictions of outcomes to be made, and *secondly*, *decision-making* to provide for the selection of the “most advantageous” outcome.

On this very general basis, I would like to suggest that appreciation and understanding of the general nature of the research function and its intimate connection to the decision-making function of management is, the *one most* important research need of the pulp and paper industry today.

THE NEED FOR EFFECTIVE DISTRIBUTION IN RESEARCH ACTIVITIES

Recognition of this fact-finding and forecasting role of research makes clear the need for research activity and personnel in nearly all fields of interest in the pulp and paper industry, e.g., raw materials, processing, product qualities, materials of construction, power requirements, engineering designs, cost analysis, market forecasts, financial forecasts, and even personnel performance predictions.

Research in all these fields, and others too, is needed but some research forecasts are more urgently required than others for decision-making in favor of company developments and profit.

So a company maintains its own laboratory organization in which what I shall call *Company Research* is conducted to obtain specific and confidential performance forecasts of immediate and urgent competitive interest. Other interests of a company may be less weighted with competitive status and may be common with other companies. Research reflecting these interests, I shall call *Industry Research* and this is usually conducted in research institutes or universities. Still other interests of a company may be longer term and may be common with many other companies in a variety of different industries or other units of society and may provide a good vehicle for teaching students. These general interests are reflected in today's *University Research*.

Of course there is often overlapping among the activities conducted as *Company Research*, *Industry Research*, and *University Research*, but each of these is different and significant. Thus I think that another important research need of the pulp and paper industry is the need to recognize to an increased degree the separate role of each of these three types of research, and to support each of the three in a clearly planned and balanced manner so that their respective contributions will continue to be available in the future.

POSTULATES FOR RESEARCH

Research is expensive and time consuming, so careful selection must be made of the particular fields in which research is to be conducted. Certain objectives of research activity can be tentatively specified from the viewpoint of the pulp and paper industry, but the selection of research objectives is subject to continuing reexamination in the light of new findings and developments.

Some general postulates which certainly bear upon research needs in the pulp and paper industry seem to me to be the following:

Postulate I—Population Growth in the United States will continue at a substantial rate.

Thus market potential continues to expand, but these new markets must be won and held against competitors.

Postulate II—The costs of scientific and technical, and especially of research manpower will steadily increase.

The increasing mechanization of industry is requiring increased training and skills and intelligence in the persons engaged in industrial work. Research per-

sonnel of the high quality must be recruited and maintained to achieve the research needs of the pulp and paper industry.

Postulate III—The pace of scientific discovery and of engineering and technological application will continue to be rapid.

We heard again this morning that 90 per cent of all the scientists ever born are still alive today. Thus we emphasize the continuing growth in supply of scientifically trained people. *But*, this same percentage was apparently still appropriate in 1680, the time of Sir Isaac Newton. We may expect the tempo to continue to be rapid and perhaps further increase, and appreciation of this trend seems vital.

Postulate IV—Inter-industry competition will increase.

In recent years we have seen steady extension in the competition between two or more industries that used to be regarded as unrelated. We have seen the partial displacement of glass milk bottles by paper cartons, of glassine and cellophane films by polyethylene and other films, and of wooden boxes by paper cardboard boxes. We see the fierce battle being waged between rayon and nylon for the tire cord market. This inter-industry competition will certainly steadily increase.

Postulate V—Foreign competition for pulp and paper markets will increase.

Because of increasing activity overseas in the pulp and paper industry of foreign countries, increased competition seems inevitable.

Postulate VI—The capabilities of high speed calculating machines will steadily increase.

I submit that man's capacity to do high speed machine calculation is revolutionary in its implications for our society and particularly for industrial operations, research and management.

Postulate VII—Power may become relatively much cheaper in the future than is now the case.

It is true that nuclear engines are not yet generally competitive, but competitive prices for fission type power are being approached. The real promise of cheap power lies in the nuclear fusion type power which is probably ten to fifty years away. But things of this sort always seem to arrive sooner than expected, so we should expect changes and plan for it.

These then are some postulates which certainly influence the selection of, and the possibility of achievement of, the ten very general research needs which I shall now suggest in order of process interest and with particular reference to the next ten years.

TEN RESEARCH NEEDS FOR TEN YEARS

Need I: To establish a much better understanding of the relationships between the properties of pulp and paper industry consumer products with properties of the intermediates and with the original woody tissue and the cellulose, lignin and other components therein.

Until recently, not much has been done about this need, I suppose, because an individual company does not usually have much control over the particular species or individual trees available in its forest lands, and also because of the large influence of process variations on the characteristics of the final products. However, to move seriously now in the direction of tree breeding, and to take advantage of the recent achievements in the field of genetics, some basic information seems to me to be quite urgently needed.

But, if one is to go in for tree breeding, then what kind of tree does one want to breed? What species and variety and individual? To breed for what? Are we now speaking of cellulose produced per acre per year, or of fiber length or of high or low percentage lignin, or high or low percentage of cellulose, or of particular characteristics within the cellulose such as angle of spiral and assembly of fibrils in a cell wall, etc. Answers to questions of this sort must be provided soon.

Industry Research, aided by *University Research*, will provide these answers, and *Company Research* will point the way to specific applications within each industrial company.

Need II—To establish knowledge and practice for effective pulp and paper tree breeding.

The natural next level of development of forestry techniques, beyond all the steps of protection of forests from fire and organisms and beyond the establishment of sustained yield and optimum harvesting programs, seems to be the breeding and planting of particular species and types of trees thought to be potentially useful and most profitable for maintaining in the forests of pulp and paper industry.

Radiation techniques are now well established for speeding up mutation rates but the evaluation of mutants must be established. Also needed are ways to decrease the *time lag* between the actual step of mutation and the step of evaluation of the fiber out of the raw material and the finished fiber. How long must it take for a mutant seed to grow sufficiently into a young tree to permit the tree to be evaluated by its utility in the field. Whatever the present answer is, it is obviously much too long.

This breeding research seems particularly appropriate to conduct as generalized *Industry Research* and *University Research*.

Need III—To expand knowledge of how to grow trees.

A tree is an organism which has a wonderful power to collect energy from the sunlight and use this to convert carbon dioxide from the air into the substance of the tree with the help of water, metals and other substances available from the earth. Of the very large number of factors influencing tree growth, it seems to me that there is an immediate research need to establish more closely the requirements and relative advantage of use of various chemicals which may function as "fertilizers" or to satisfy "deficiencies" in growth of trees. This is, of course, a complex problem in chemistry, diffusion, and the characteristics of soils. But it is also a research which must include economic evaluations. Thus, here, it is

especially necessary to conduct *Company Research*, *Industry Research* and *University Research* in a closely correlated fashion.

Need IV—To substantially improve techniques of tree harvesting.

Here is an immediate important research area in a field which started out with use of power provided by men and horses and elephants, and now, in the U. S., at least, is extensively mechanized. But as one who is a professional engineer, it seems to me that surely much more can be done. I understand that tests are underway on a machine which permits the continuous harvesting of trees of modest age and this appears to be a promising approach in this field. It also seems to me that much needs to be done to improve the methods for mechanically separating the woody tissue, the bark tissue, and indeed the needles.

Research on harvesting is apparently primarily of the Company and Industrial type because of its immediate relationship with specific processing costs.

Need V—To improve mechanical and semi-chemical pulping and the properties and uses of mechanical pulps.

Mechanical and semi-chemical pulp production and transformations with emphasis upon ways to marry fibers to plastics and polymers seems to me to be a research field which will be of continuing significance.

Need VI—To improve chemical pulping, and the properties and uses of cellulose for papers.

The long separation of sulfite from Kraft procedures now appears to be disappearing with the apparent evolution of one more or less standard but highly versatile continuous chemical pulping process whereby desired properties in the product can be obtained by modification in operating conditions.

As *Company* and *Industry Research* proceed to complete this process problem, it may be well to keep in mind that although the use of paper has a two thousand year history, there are new strong influences pressing toward the introduction of new materials and alternative techniques of transmission and preservation of the idea and the word. The world's libraries are increasing at tremendous rates such that today at least the universities can hardly afford to keep the pace in providing capital monies for construction, and operating monies for librarians and related materials. The time is ripe for some new developments, and the paper industry may well find serious competition coming to it within the next several decades. Paper in the field of containers, wrapping paper, may likewise find substantial competition coming from other chemicals synthesized into films of specialized properties.

Need VII—To improve chemical pulping and the properties and uses of cellulose for chemical purposes.

It seems to me that there is great need for research which would lead to major simplification of the long line of processes starting with the wood and ending up with chemical cellulose pulps and finally with cellophanes or cellulose derivatives. Can we expect a long survival for such a complicated series of processes

with the attendant costs and difficulties in control? Surely something can be done to streamline all this into one straight line system with wood chips or sawdust coming in one side of the process and cellulose rayons, textile materials, or films, or plastics and other useful materials coming out the other side.

Another research need is for much more information about the characteristics of cellulose fibers as well as regenerated celluloses and cellulose derivatives. Properties of regenerated cellulose film and derivatives seem in urgent need of improvement.

The research needs in these fields seem to me to be of outstanding urgency for the very preservation of major industrial activity. *Company*, *Industry* and *University Research* are all needed now.

Need VIII—To improve knowledge and uses of by-products of chemical pulping.

Consideration of the non-cellulose by-products of chemical pulping begins with a heritage of pollution which is today still of importance around the world. Steps have been taken in the Kraft industry and are now being developed for the sulfite pulp industry to provide for at least partial avoidance of pollution by collecting and burning the non-cellulosic wood components. This utilization of the non-cellulose components of wood for fuel is certainly a desirable step forward, but we may soon find that nuclear fuel sources are cheaper.

We should vigorously continue to conduct research directed toward the development of higher grade uses for the non-cellulosic wood components. Lignin is, of course, the main by-product and much more fundamental knowledge about lignin is still urgently needed from University and Industry laboratories. However, vigorous application research in Company Laboratories is also required so lignin products can finally be made and sold in a competitive market on a large scale, and at a profit. To a lesser degree, one may make similar remarks about the non-cellulose sugar components of the wood, i.e., what is needed is more *University* and *Industry Research* on the nature and reactions and characteristics of these compounds, as well as *Company Research* in individual company laboratories looking toward particular uses and markets.

Need IX—To improve data processing procedures to aid for pulp and paper industry management.

The advent of machines for recording data and permitting rapid analysis of very large amounts of data provides opportunities for improvements in management procedures which should perhaps be exploited more generally throughout the pulp and paper industry.

Production, costs, markets, designs, inventory, forests, engineering and personnel can now be studied effectively on a basis wholly different from that possible ten or even five years ago. He who does not intensify the pace of internal or *Company Research* on data processing and management decision-making methods will suffer dearly during the next ten years.

Need X—To improve research personnel, organization, and management in the pulp and paper industry.

The pulp and paper industry is perhaps behind many other industries in the use of research personnel and organizations within the industry and outside the industry to advance its purposes. Only since World War II has there been developed in a number of major companies of the pulp and paper industry research personnel and organizations of real stature and promise. An important research need of the industry is the steady increase in quality and number of research personnel and in the organization and effective use of those personnel. The universities strive to provide outstanding able candidates but the industry must provide real opportunities and rewards for these men.

These then are my ten research needs.

THE YEARS BEYOND

In conclusion, let me remark on some longer term research prospects which may well be fanciful, but stimulating.

In recent years truly astounding advances have been made in the understanding of the functioning of living organisms. Now established in a fairly firm fashion are a number of the basic metabolic cycles. Inheritance and mutation phenomena are now being studied with potentially very great fruitfulness in the fields of genetics. Knowledge of molecular structure of biologically significant molecules is being secured at an astonishingly rapid rate. These findings will all certainly influence genetics and breeding as applied to trees.

Related to these developments in genetics are complimentary developments in biochemistry and other fields of molecular biology. The structure and action of enzymes, the procedures of physiology and pathology are being found out.

Some day soon it may well be possible to synthesize cellulose molecules without the need for the tree itself. One can visualize photosynthetic activity conceivably using isolated enzymes or synthetic enzymes functioning under synthetic sunlight (perhaps tens or hundreds of times as strong as natural light), providing for conversion of carbon dioxide into selected sugars, and these in turn being aligned by enzymes means into cellulose and other polymers or derivatives. Assembly of cellulose molecules into fiberils and fibers may be a later development.

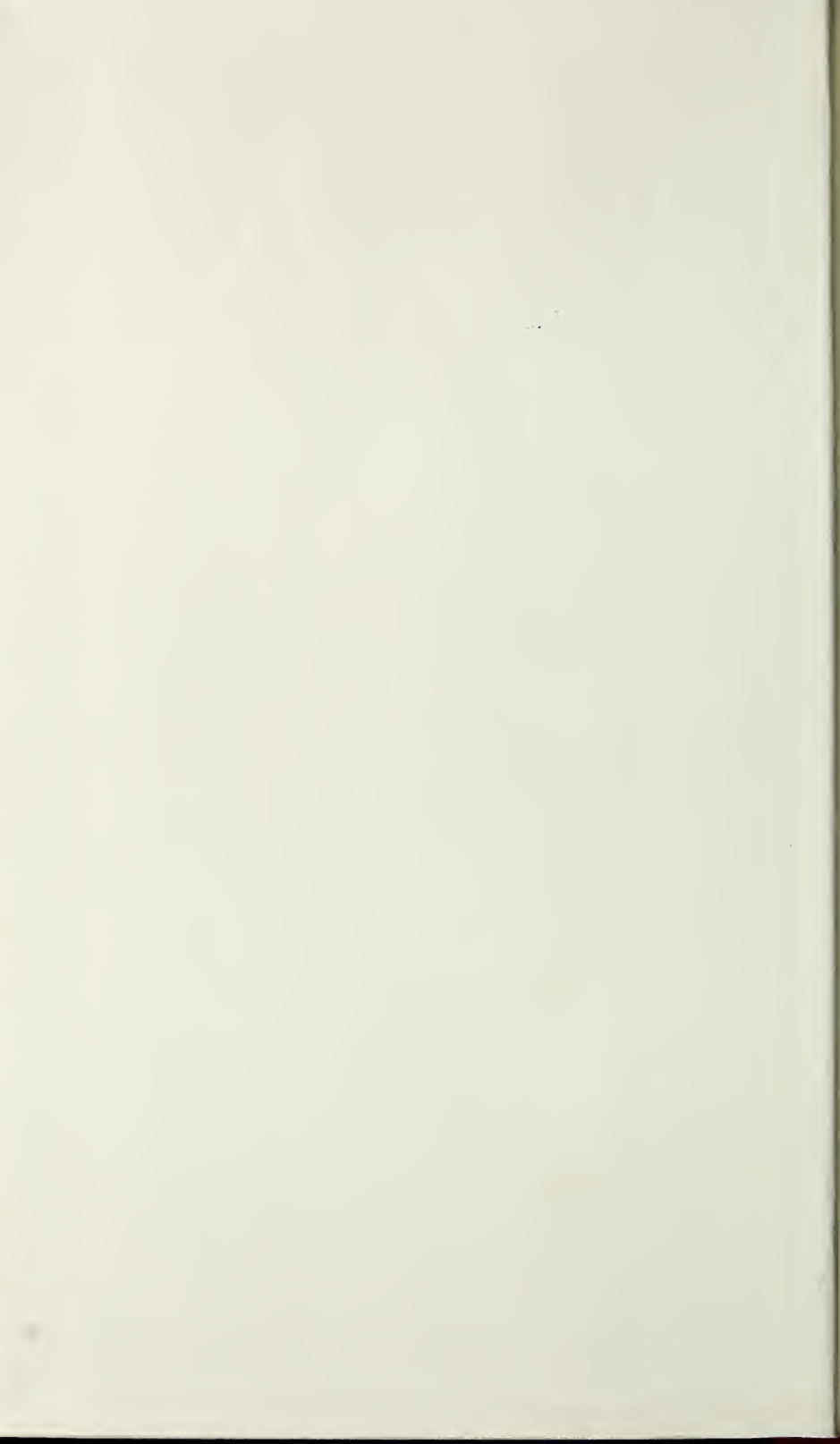
What man can dream—he can very often do—and soon.

Man's research need is the need to know today, tomorrow, and the day after tomorrow too!







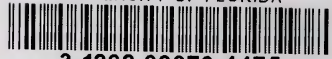


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